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Blast Furnace Cast House Emission Control Technology Assessment

Betz Environmental Engineers, Inc, Plymouth Meeting, Pa

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, N C

Nov 77

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November 1977

PB 276 999

Environmental Protection Technology Series

BLAST FURNACE CAST HOUSE EMISSION CONTROL TECHNOLOGY ASSESSMENT

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16. ABSTRACT The study describes the state-of-the-art of controlling fumes escaping from blast furnace cast houses. Background information is based on: a study of existing literature; visits to blast furnaces in the U.S., Japan, and Europe; meetings with an ad hoc group of experienced blast furnace operators and engineers appointed by the American Iron and Steel Institute; and a questionnaire sent by AISI to all its members (the questionnaire resulted in operating and physical characteristics data on 151 standing blast furnaces). The limited emissions data available at the start of the study had been obtained through the use of various rather imprecise methods. To obtain additional more precise data, approval was obtained from Dominion Foundries and Steel, Ltd., to sample emissions from its No. 1 blast furnace cast house using EPA sampling methods. (This furnace employs full emissions control using a total cast house evacuation technique.) Existing cast houses were classed according to major factors influencing control scheme selection. For yet-to-be-design cast houses, suggestions are made for optimizing the integration of cast house emission control. For both retrofit and new classes, technology gaps are identified and the nature and scope of suitable development programs are proposed to fill these gaps.

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November 1977

BLAST FURNACE CAST HOUSE EMISSION CONTROL TECHNOLOGY ASSESSMENT

by

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Contract No. 68-02-2123
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EPA Project Officer: Robert C. McCrillis

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Prepared for

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Office of Research and Development
Washington, D.C. 20460

FOREWORD

The United States Environmental Protection Agency (EPA) contracted with Betz Environmental Engineers, Inc. to produce a report on the emissions from and state-of-the-art of emission control for blast furnace cast houses. EPA has reviewed the produced document and has decided that many of its conclusions are not based upon scientific information contained in the report. Examples of statements which EPA has decided are erroneous and/or unsupported by the study are found on pages 4, 55, 66, 106, 125, 128 and 141. These representative statements are as follows:

page 4 -

> "Although this study does not specifically address the point, the investigators feel that there probably is a blast furnace and cast house size combination for which the economic burdens of cast house fume control, through either partial or total capture, cannot be justified on economic grounds."

page 55 -

> The entire section entitled "Pollution from Power House Caused by Control of Emissions from Cast House."

page 66 -

> The statement "Government support of steel industry" referring to the Japanese steel industry.

page 106 -

> "These modifications to materials and operating procedures would provide some cast house emission control with little or no increase in energy consumption, and, therefore, would not increase pollution from energy producing sources." (emphasis added)

page 125-128 -

> Figures 7-15 through 7-17 relating power house emissions to cast house emission control.

page 141 -

> The section entitled "Safety Considerations".

JKBurchard
John K. Burchard
Director
Industrial Environmental
Research Laboratory-RTP

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ACKNOWLEDGMENTS

We are particularly grateful to the American Iron and Steel Institute for the ad hoc committee which assisted in our efforts to obtain technical background and operating procedures on blast furnace operations. Without this assistance we would have had less potential to visit blast furnace installations and learn some of the operating procedures first hand. Individuals on this committee contributed freely of their time to help us in this program.

We gratefully acknowledge the cooperation given us by DOFASCO which allowed free rein in our testing efforts and permitted access to all of its available operating information. Without this assistance we would not have had sufficient quantitative emission information on which to base our efforts.

The steel industry in all parts of the world showed active interest in this project and offered supportive assistance.

The EPA Project Officer was Robert C. McCrillis of the Metallurgical Process Branch, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina.

SECTION 1

INTRODUCTION

This report is concerned with the definition of technology for controlling blast furnace cast house fugitive emissions which implies the existence of the need to control such emissions. The contract scope-of-work, which this report addresses, did not direct B.E.E. to evaluate the impact of cast house emissions on ambient air quality.

Because domestic environmental control efforts and resources have been concentrated in other areas, the priorities given to controlling these emissions has been low. Consequently, the state-of-the-art for reducing blast furnace cast house emissions has not been extensively developed in the United States.

This study focuses on the state-of-the-art of curtailing or controlling the escape of fumes from the cast house. This study also considers the nature and scope of further studies which may be required to furnish data which would enable EPA to evaluate the feasibility and engineering aspects of cast house controls.

The approach employed to obtain data for the many variables was to submit a questionnaire to all the operating blast furnace plants. (A copy of the questionnaire is presented on page A37-A39 in Appendix A). The development and transmittal of the questionnaire was accomplished through the AISI ad hoc committee which was comprised of members representing the operating, environmental, and engineering groups of steel firms. Meetings with the ad hoc committee were held periodically to up-date the proceedings and to provide answers to B.E.E. questions. This committee was also instrumental in arranging domestic plant visits for the investigators.

Prior to initiating meaningful discussions with the AISI ad hoc working group B.E.E. agreed to provide the AISI an opportunity to critique a draft of the report. Comments prepared by the AISI ad hoc committee and the Industrial Environmental Research Laboratory of EPA on this study appear in the report.

To aid in the study, improved quality cast house emission data was necessary. Because casting emissions are fugitive in nature, existing data available at the initiation of this study consisted of cast house emission factors developed through the use of various methods, such as time lapse photography and sampling in cast house roof monitors using inverted high volume ambient samplers. Such methods are less precise than the present state-of-the-art for quantifying stationary source emissions. To obtain additional data, B.E.E. obtained approval from Dominion

Foundries and Steel, Limited (DOFASCO) to sample emissions from its No. 1 blast furnace cast house using EPA sampling methods. This furnace employs full emission control using a total cast house evacuation technique. Air volumes exhausted, pounds of particulate removed, as well as ambient conditions in the cast house are reported in Section 5.

This report employs iron making and blast furnace terminology. To aid the reader, a technical glossary is included beginning on page 156.

SECTION 2

CONCLUSIONS

The technology of blast furnace emission control through ventilation and/or emission reduction needs further study and development. Technology for emission reduction through fume cleaning exists and can be accomplished by any number of air pollution control devices, including wet scrubbers, fabric filters (baghouses) and, to a lesser degree, mechanical collectors. The fabric filter, however, as reviewed in Section 5 is the most suitable control device for this application. Doubt exists as to the effectiveness that can be expected from a dry electrostatic precipitator due to particulate matter characteristics. The results of this study program further indicates that through process modifications (including development and application of materials and operating practices) the generation of objectionable emissions can be reduced, but the extent is presently unknown.

At the initiation of this study, particulate emission factors in the order of 0.1 to 0.15 Kg per tonne (0.2 to 0.3 lbs. per ton) of hot metal cast were considered representative. Based upon sampling conducted by B.E.E. employing EPA methods at DOFASCO, in Hamilton, Ontario on its blast furnace cast house No. 1 and sampling by Bethlehem Steel Corp. on its Johnstown "E" blast furnace while casting basic iron, an emission factor range of 0.1 to 0.3 Kg per tonne (0.2 to 0.6 lbs. per ton) may be more appropriate. Both of these sampled facilities utilize total cast house evacuation to capture emissions. Additional cast house emission testing is needed to better define fugitive emissions. Based upon B.E.E.'s observations during casting of 16 domestic furnaces, it is inappropriate to consider a single emission factor for all basic iron casting operations. The high value of the 0.1 to 0.3 Kg per tonne range of emission factors was obtained from the DOFASCO testing program, and it is B.E.E.'s judgement that the casting operation at this facility generated above average fume quantities. The observed differences in the levels of fume generated from cast house to cast house can be attributed to variations in operating practices and materials used in the blast furnace and cast house.

DOFASCO conducted a program (Table 5-4) over a three month period (September - November, 1976) which consisted of weighing the dust collected in the hopper of the dust collector serving cast house No. 1 and relating this amount to tons of metal cast. The average emission factor obtained was 0.26 Kg/tonne of hot metal cast (0.52 LBS/T). Section 5 reviews the development of emission factors.

There is one operating cast house emission control system in the United States on a ferromanganese blast furnace and none on blast furnaces regularly producing basic iron. The installation employs total cast house evacuation, an approach that is energy intensive since it involves movement of large volumes of air.

The Japanese steel industry has developed alternative technology for cast house emission controls. During the past ten years they have developed their systems to the point where they now have integrated their iron making and emission control systems. Primarily, the Japanese approach is fume capture at the source through the use of close fitting hoods and covers wherever the hot metal is exposed to the atmosphere inside the cast house. The state-of-the-art of cast house emission control is discussed in Section 6. Japanese blast furnace and cast house physical characteristics, as well as operating practices, differ from those in the United States and it is these differences that may preclude successful direct application of Japanese technology to United States facilities. Much will be learned about this technology when it is applied to the United States blast furnaces under construction in Maryland and Indiana.

The Japanese partial control concept has advantages and may show promise upon further development. This concept approaches emission capture by applying ventilation where it can be most effective, in the tap hole and iron trough zones of the cast house. These are the zones where particulate matter concentrations have been observed to be greatest.

Although this study does not specifically address the point, the investigators feel that there probably is a blast furnace and cast house size combination for which the economic burdens of cast house fume control, through either partial or total capture, cannot be justified on economic grounds.

"Although the report deals with methods of controlling blast furnace cast house emissions, the AISI ad hoc committee believes that the implementation of any such technology should be based on ambient air quality considerations. There are not any air quality data presented which demonstrate that blast furnace cast house emissions have a substantial impact on ambient air quality."(1)

"Given that (1) most iron and steel plants are in non-attainment areas and (2) casting of hot metal from blast furnaces produces an observable emission exiting the cast house, then it is reasonable to conclude that cast house emissions do have a detrimental impact on ambient air quality. The State of Maryland Bureau of Air Quality Control concluded in October 1974 that the blast furnace cast houses in a large iron and steel plant in that State contribute substantially to the high particulate concentrations experienced at nearby monitoring stations and that

(1) AISI ad hoc working group prepared comment

air standards would probably not be met unless blast furnace cast houses were controlled in addition to those sources already subject to a compliance plan."(2)

---

(2) EPA Industrial Environmental Research Laboratory prepared comment.

SECTION 3

RECOMMENDATIONS

Continuing effort is necessary to provide a practical answer to the curtailment of cast house emissions. Data and technology which are presented in this preliminary study are not sufficient in depth to specify a method of abatement that would justify the expenditure of large capital funds. The data acquired under the scope of this contract are not extensive enough to set an emission rate pattern. Concepts advanced have not been proven through demonstration activities, but are set forth as ideas, or suggested as methods to follow.

B.E.E. recommends that the following additional programs be pursued to quantitatively arrive at values which could be applied effectively to all cast houses to achieve a practical system(s) of emission control:

1. Conduct additional extensive particulate matter emission testing using state-of-the-art techniques at future new and retrofitted blast furnaces which have emission capture systems to establish a data base for quantity and classification of effluents from cast houses.

2. Conduct a two-phase study and demonstration program to determine the emission reduction potential of process modifications. The first phase should be a paper-type study to determine the need and the details of direction to be followed in an in-depth study of production procedures, materials and practices, which could reduce the generation of emissions from casting.

   Based upon the results of the first phase study, conduct a demonstration effort to quantitatively assess performance of pre-selected process modifications and materials in reducing generated emissions.

3. Encourage the development and demonstration of an effective and acceptable partial control system for the

tap hole and iron trough zone. One or more of the concepts in this report could be designed and adapted to existing cast houses. This program would be an engineering plus installation and performance effort.

4. Conduct an investigative-type program to assess the suitability and operative qualities of the Japanese control systems used on new, United States cast houses. This program would prove or disprove the practical aspects of operation and economics of the new systems as they relate to United States iron producing practices and would provide a basis for modifications in design, if necessary.

Section 10 outlines the scope of the above studies and estimates costs and schedules required to complete the studies.

SECTION 4

PROFILE OF IRON PRODUCING OPERATIONS

BLAST FURNACE PROCESS DESCRIPTION

The blast furnace is a large cylindrical shaped reactor into which coke, iron ore and limestone are charged at the top. Hot air is blown in at the bottom of the furnace through tuyeres. The combustion of the coke provides the heat and reducing gas to reduce the iron oxides to iron and to provide the heat to melt the iron and other impurities in the charge. As the iron moves downward through the furnace, it is heated by the upward flow of gas and chemically reacts with the CO and hydrogen in these gases to remove oxygen from the ferrous oxides. See Figure 4-1, Blast Furnace Cross Section.

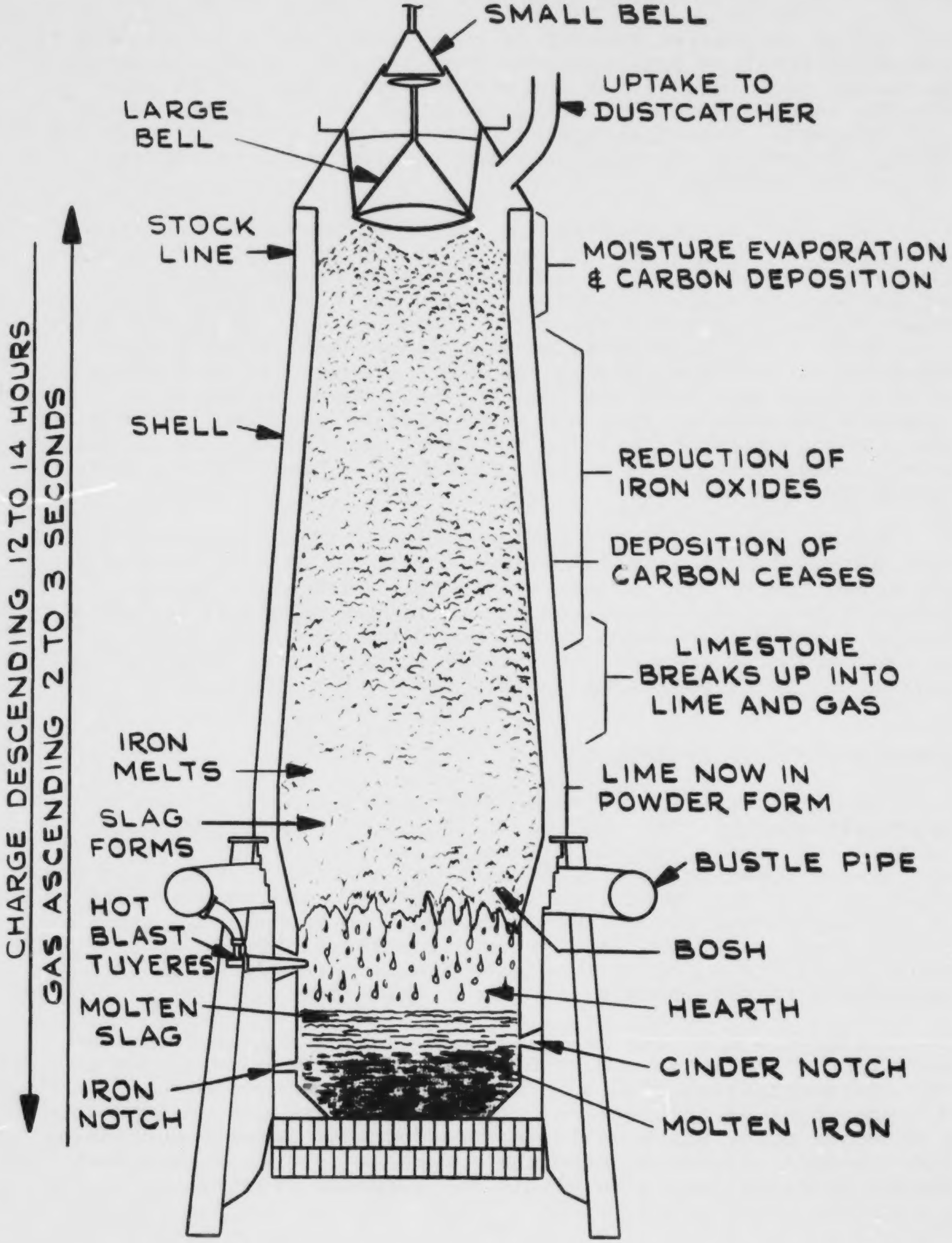
The impurities in the ore, called gangue, are melted in the lower zone of the furnace and chemically combine with the limestone and coke ash to form slag. Limestone and/or dolomite is added in the correct portions to control the slag chemistry. With the proper ratio of constituents, the slag melting temperature, viscosity, and sulfur removing capabilities can be controlled. The limestone and dolomite that are added at the top of the furnace, are in the form of $CaCO_3$ and $MgCO_3$ and these compounds are calcined during their decent in the furnace and arrive in the melting zone as CaO and MgO.

The molten iron and slag are collected in the hearth of the furnace and are periodically removed. To remove the iron and slag, a small diameter hole is drilled through the furnace wall into the hearth. The iron and slag flow out through this hole in to the iron trough. The iron trough is located in the cast house floor at the tap hole and accumulates approximately 3 to 12 cubic meters (106 to 424 cubic feet) of molten metal, which is topped by the lighter slag. When the trough is full, a skimmer and dam at the outlet end of the trough separate the metal and slag so that they exit the cast house from separate runners, which are essentially troughs formed into the cast house floor by packing clay and silica sand into a metal form. The slag is carried through its runners to either a granulation facility, open dry slag pits or slag ladles. The iron flows by gravity in its runners and is collected in ladles adjacent or underneath the cast house floor.

In general, as the temperature of the molten iron increases, the silica increases and the sulfur decreases in the hot metal. The control of the hearth temperature is effected by the flame temperature at the tuyeres which in turn is controlled by hot

Figure 4-1

BLAST FURNACE CROSS SECTION


SMALL BELL
UPTAKE TO DUSTCATCHER
LARGE BELL
STOCK LINE
MOISTURE EVAPORATION & CARBON DEPOSITION
SHELL
REDUCTION OF IRON OXIDES
DEPOSITION OF CARBON CEASES
LIMESTONE BREAKS UP INTO LIME AND GAS
IRON MELTS
LIME NOW IN POWDER FORM
SLAG FORMS
BUSTLE PIPE
HOT BLAST TUYERES
BOSH
HEARTH
MOLTEN SLAG
CINDER NOTCH
IRON NOTCH
MOLTEN IRON
CHARGE DESCENDING 12 TO 14 HOURS
GAS ASCENDING 2 TO 3 SECONDS

blast temperature, fuel injection rate, moisture injection rate and oxygen injection rate.

The gases leaving the top of the furnace are first cleaned in a gravity settling tank called a dust catcher, where the larger particles contained in the gas are removed. The gas is then cleaned in a high energy venturi scrubber and cooled to remove any moisture. The clean cooled blast furnace gas is used in the stoves to preheat the blast air and in steam boilers for the generation of steam.

The blast air is supplied by large compressors which are either driven by a steam turbine or an electric motor. In most integrated steel plants, the blast furnace blowers are steam driven because steam is available from the boilers that burn the blast furnace top gas. The air is then heated in a regenerative type stove to a temperature between 1000°C and 1250°C before being blown into the furnace through the tuyeres. Each furnace will usually have three or four stoves. These stoves will normally be operated with one stove heating the blast air and one stove being heated by burning the blast furnace top gas in the stove. Figure 4-2 is a representation of a blast furnace with auxilliary equipment.

The objective of the individual blast furnace operator is to gain maximum production or minimum hot metal cost by optimizing the operation of his furnace within the constraints of raw material supplies, coking and agglomeration capacity, hot metal demand and specifications. The specification of the iron is controlled by adjustments in furnace practice that keep the percent of the constituents within the limits specified.

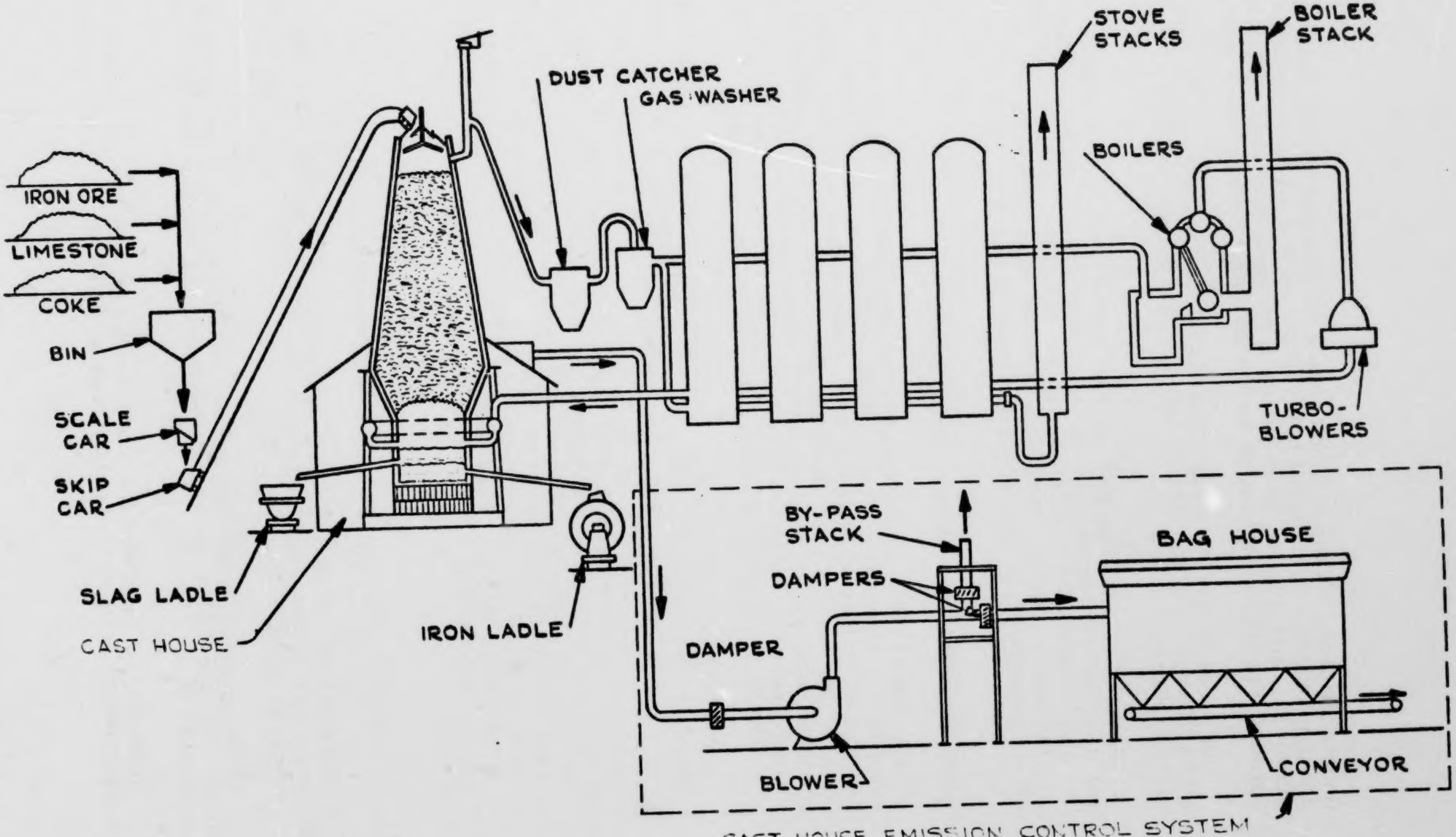
FUELS AND BURDEN MATERIALS

The size, physical strength and uniformity of the burden materials charged into the blast furnace are most important factors. However, because of availability and economics, it is not always possible to achieve ultimate control of these factors. There is some degree of relationship between the characteristics of the burden and the volume of fume at the taphole and iron trough area. Although the proper selection of burden materials could result in a reduction of the fume generated, it is impossible to eliminate all tap hole emissions.

One of the most important factors to be considered in the reduction of pollution through the use of optimum materials is the characteristics of blast furnace coke. Close control of optimum physical and chemical properties of the coke can produce a stronger coke, which could in turn decrease fume production at the tap hole. Inferior coke that degrades into fines and dust during handling, and also within the furnace, creates

Figure 4-2

BLAST FURNACE PLANT WITH AUXILLIARY EQUIPMENT


IRON ORE
LIMESTONE
COKE
BIN
SCALE CAR
SKIP CAR
SLAG LADLE
CAST HOUSE
IRON LADLE
DUST CATCHER
GAS WASHER
STOVE STACKS
BOILERS
BOILER STACK
TURBO-BLOWERS
BY-PASS STACK
DAMPERS
BAG HOUSE
DAMPER
BLOWER
CONVEYOR
CAST HOUSE EMISSION CONTROL SYSTEM

unsatisfactory furnace operation and can result in coke messes at the tap hole. The stability factor is a relative measure of coke strength, and it has been noted that when the number is below 50 furnace operation is rough and more coke messes can occur.

Generally, it is felt that ideal burden materials and coke would have a decided effect on the volume of emissions from casting operations.

Upgrading the quality of the burden materials would increase the cost of producing hot metal. However, because of the need to increase the furnace efficiency to obtain higher productivity at a lower cost, burden material studies will probably be carried out independent of any problems concerning air pollution.

PRODUCTS GENERATED BY THE BLAST FURNACE

The blast furnace operation is designed to produce molten iron with a high percentage of Fe and minor percentages of impurities, using a minimum fuel rate. The pig iron normally consists of 94.0% iron, 3-4% carbon, 0.60 to 2.0% silicon, approximately 0.03% sulfur, and 2.0% manganese. The hot metal at a temperature of about 1480°C (2700°F) flows in open runners in the cast house floor to specially built ladle cars.

The formation of slag in a blast furnace is a result of the chemical composition of fluxes and impurities. This formation occurs in the bosh and becomes molten in the hearth.

A high temperature at the tuyeres favors a good separation of slag and hot metal, and removes, as CaS and MgS in the slag, most of the sulfur that originated in the coke and supplementary fuel. The slag contains most of the lime, silica, magnesia, alumina and alkalies originally present in the ore and flux, and some ferrous and manganous oxides. Slag may exit the hearth together with the hot metal and/or may be flushed from the cinder notch at intervals.

BLAST FURNACE PHYSICAL DESIGN CONSIDERATIONS

Innovations in design and operating characteristics of blast furnaces are being advanced by the steel companies' operating and engineering personnel.

Technological advances point toward larger, more productive units, as is evident in the dimensions and output features of the new furnaces.

In order to provide for more frequent and larger casts, the runner concept, in certain instances, has been revised to provide tilting spouts, shorter runners, deeper, longer troughs and the elimination of slag pots. New furnaces now may have multiple tap holes and no cinder notch which eliminates slag flushing.

Technically the larger blast furnaces are superior and in the future, a large unit may replace several smaller units. The average output per furnace may increase many times and the fuel rate will be reduced due to more efficient operation.

New, modern furnaces will have special equipment for screening, weighing and charging the raw materials to the furnace. There will also be special hot blast stoves to heat the blast air to 1100°C to 1300°C and equipment to permit operation of the furnace at elevated top pressures of 1.5 to 3.0 atmospheres. Other technological improvements can be incorporated in the installation of a new large furnace.

CAST HOUSE DESIGNS AND FUNCTIONS

The cast house is a structure surrounding the blast furnace, enclosing the runners and operating area, and providing weather protection for the operators and equipment. This enclosure also contains the fumes generated during the cast. The mud gun for closing the tap hole with clay and also the drill for opening the tap hole are swung into position from supports adjacent to the furnace tap hole in the cast house. The local furnace operating control equipment is situated in an enclosure within the cast house. The cast house may also be used to store materials for relining runners, etc. There are many sizes, shapes and other construction variations in the existing structures. A compilation of most of the types and configurations as prepared by AISI follows.

Cast House Arrangements - United States Blast Furnaces

Single Tap Hole Blast Furnaces

I. Cast house crane runway aligned so that the crane bridge moves to or from the blast furnace proper.

    1. With hard slag pits and solid, back-filled type cast house floor. (See Figure 4-3).

        A. Slag pits at opposite end of cast house from blast furnace proper.

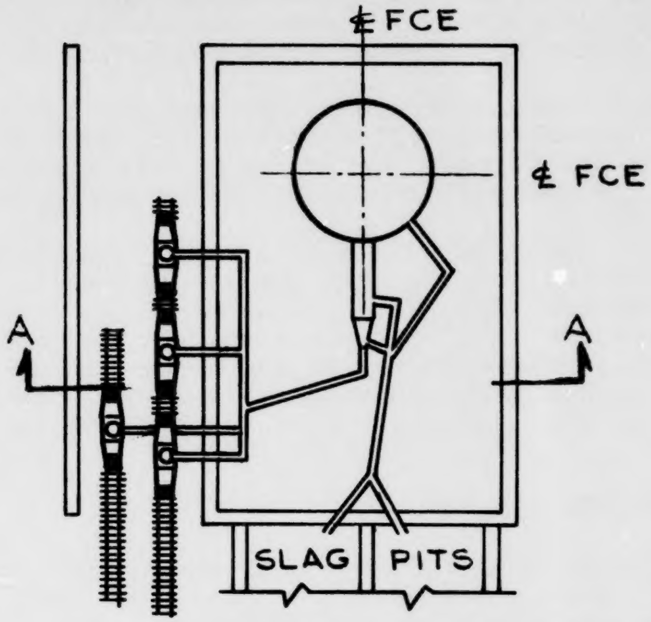
            Hot metal bottles or ladles spotted under:

            a. Lean-to.

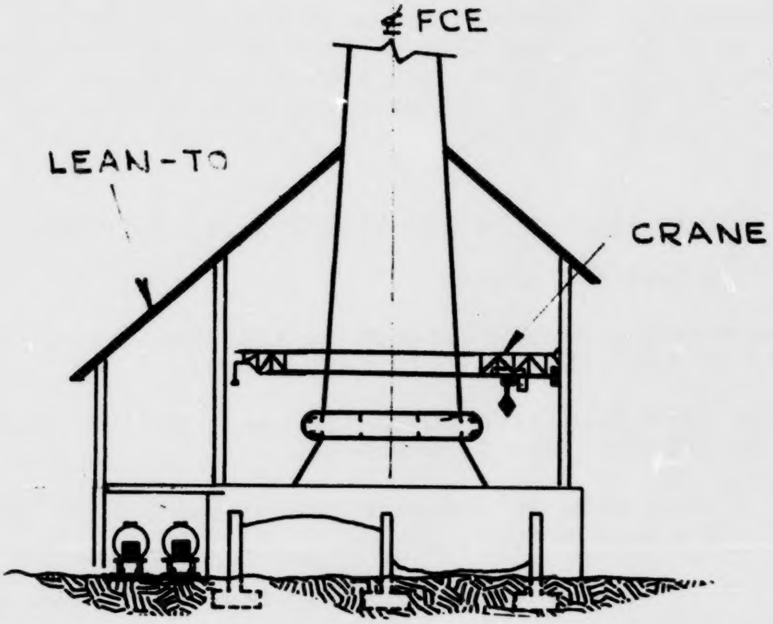
                Crucible #3

Figure 4-3

BACK-FILLED CAST HOUSE WITH CRANE PARALLEL TO IRON TROUGH WITH SLAG PITS


℄ FCE
℄ FCE
A
A
SLAG
PITS

PLAN


℄ FCE
LEAN-TO
CRANE

SECTION A-A

b. Extension of cast house roof.

Republic Warren #1

c. Under a lean-to and in an arcade under main roof.

Republic Cleveland #1 (See Figure 4-4).

B. Slag pits located adjacent to cast house building.

Hot metal bottles or ladles spotted under:

a. Lean to.

YS&T Brier Hill #2, YS&T Indiana Harbor #2; Hanna Furnaces #1, #3, and #4

b. Under a lean-to and in an arcade under main roof.

Republic Cleveland #4; Kaiser #1, #2; U.S.S. - South Works #10

2. With hard slag pits and open cast house floor (not backfilled to yard level).

A. Slag pits located at opposite end of cast house from blast furnace proper.

Hot metal bottles or ladles spotted under:

a. The main cast house floor and roof.

National Great Lakes "A", U.S.S. - Lorain Nos. 3 & 4

B. Slag pits located adjacent to the cast house building and

With hot metal bottles or ladles spotted under:

a. The main cast house (Fig. 4-5).

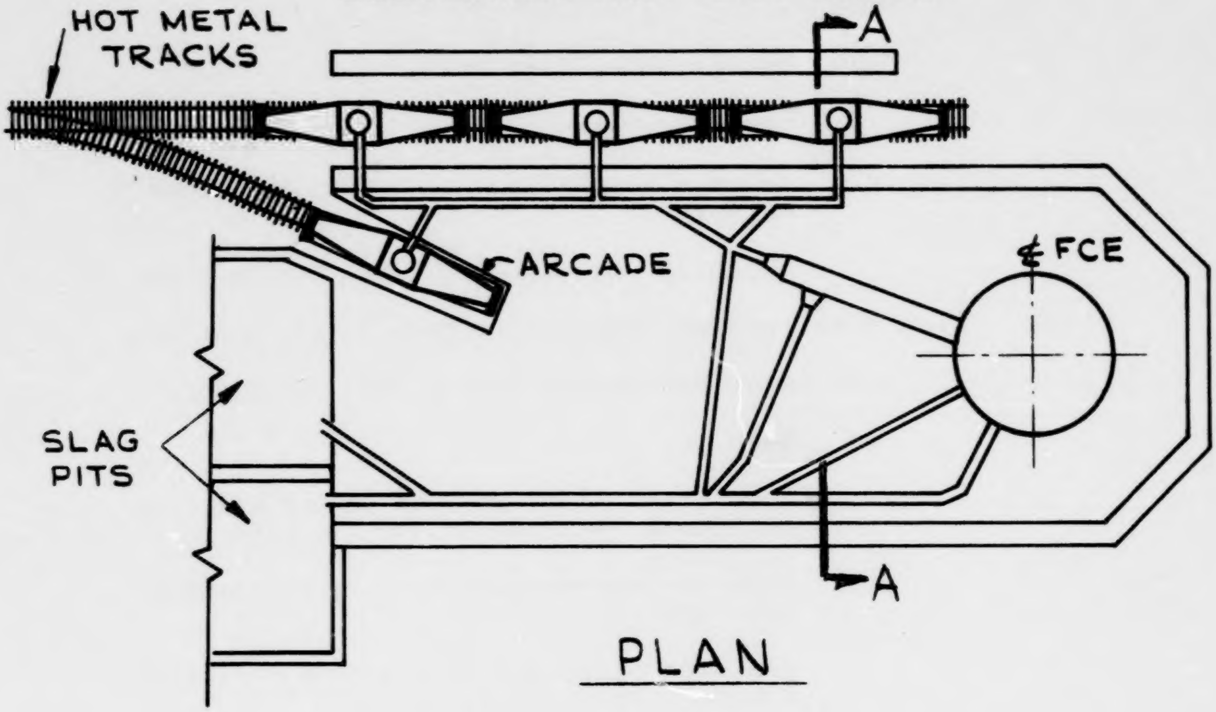
YS&T Indiana Harbor #1 & #3; Interlake Chicago "A" & "B"; McLouth #1 & #2; Lone Star #1, National Great Lakes "C"; Inland "A" & "B"; Armco Bellefonte*, Armco Amanda**; U.S.S. - Fairless #1, #2, #3,

---

*Will have hard slag pits after current reline

**Work 25% complete on cast house for second tap hole

Figure 4-4
CLEVELAND NO.1 CAST HOUSE


HOT METAL
TRACKS
A
ARCADE
℄ FCE
SLAG
PITS
A
PLAN

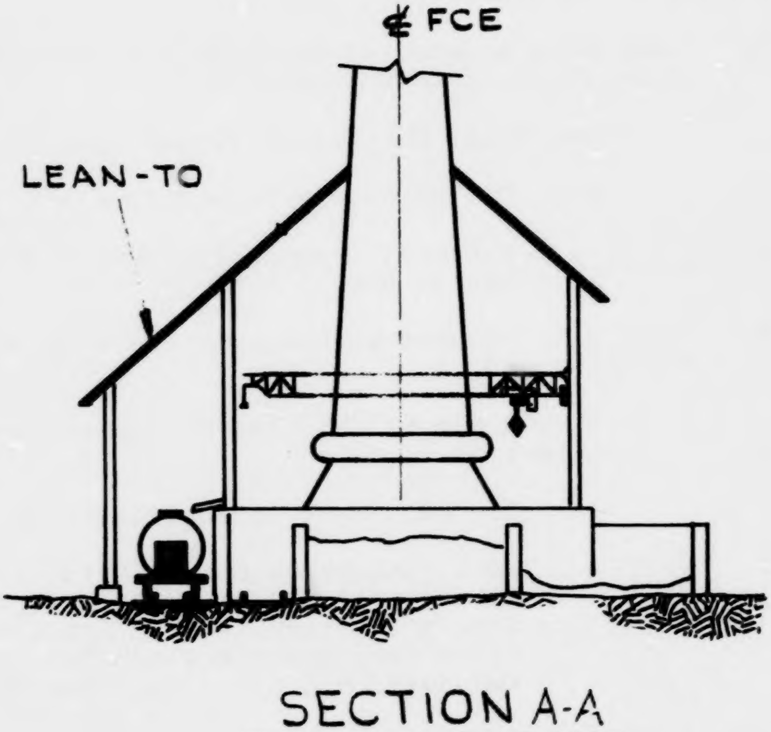
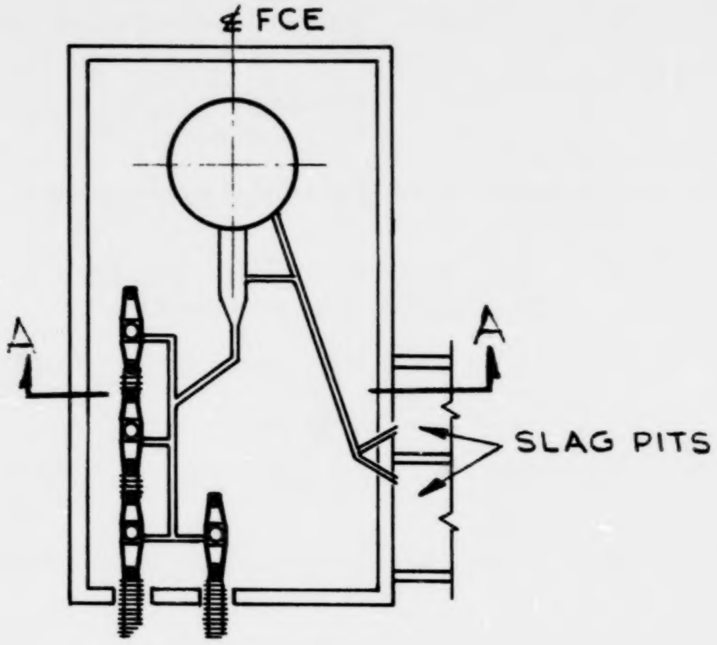
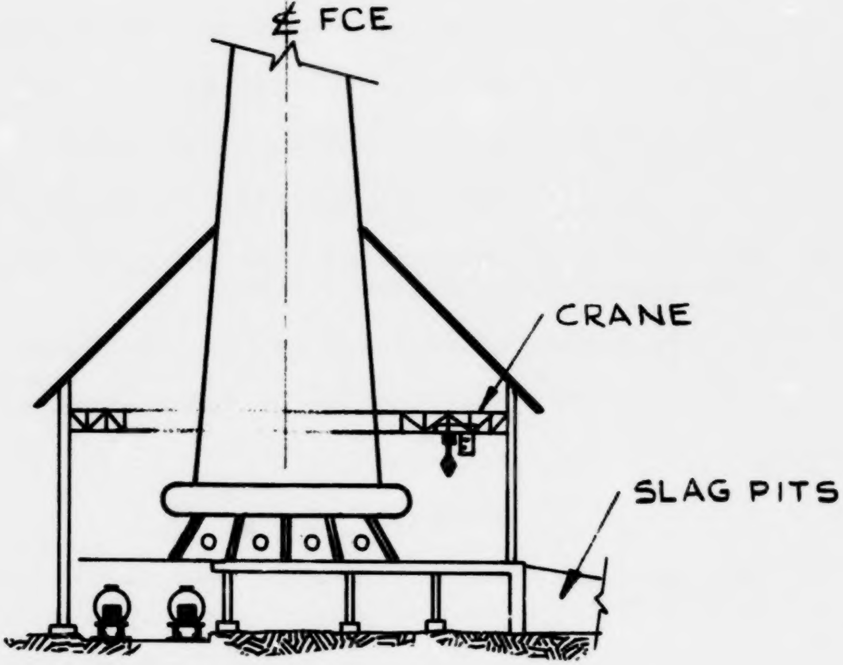

℄ FCE
LEAN-TO
SECTION A-A

Figure 4-5

OPEN CAST HOUSE WITH CRANE PARALLEL TO IRON TROUGH


℄ FCE
A
A
SLAG PITS

PLAN


℄ FCE
CRANE
SLAG PITS

SECTION A-A

U.S.S. - South Works Nos. 11 & 12.

b. Under a lean-to and under the main cast house floor:

Republic Gadsden #2, Great lakes "B" & "D"; Kaiser #4

3. Granulating or pelletizing pits and a solid cast house floor

A. Pits located at opposite end of cast house floor from blast furnace proper.

Hot metal bottles or ladles spotted under:

a. Lean-to.

Republic Buffalo #1

B. Pits located adjacent to the cast house building and: (Figure 4-5).

Hot metal bottles or ladles spotted under:

a. Lean-to.

Shenango "A";Alan Wood #2 & #3

b. Main cast house roof in an arcade.

Republic Buffalo #2

c. Lean-to and main cast house roof in an arcade.

YS&T Campbell #1, #2, #3, & #4

4. Granulating or pelletizing pits and open cast house floor (not back-filled to yard level).

A. Pits located adjacent to the cast house building and:

Hot metal bottles or ladles spotted under:

a. Lean-to.

Shenango "B"

5. With slag pots and solid cast house floor (back-filled to yard level).

A. Slag pots spotted under a lean-to and hot metal bottles or ladles spotted under:

   a. Lean-to.

      Republic Youngstown #2; Wheeling-Pittsburgh Jane; U.S.S.-Geneva #1

   b. Cast house roof in an arcade.

      Interlake Toledo "B"*;, U.S.S.-Gary Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, & 12; U.S.S.-Homestead Nos. 3, 4 and 6 & 7**

B. Slag pots and hot metal bottles or ladles spotted under a cast house roof extension.

   J&L Aliquippa A-5; Bethlehem Johnstown "G"

C. Slag pots spotted under cast house roof extension and hot metal ladles under a lean-to.

   Bethlehem Lackawanna "B"

D. Slag pots spotted under cast roof extension and in arcade under main roof and hot metal bottles under a lean-to.

   National Weirton #4

6. With slag pots and open cast house floor.

   A. Slag pots spotted under an extension of the main cast house roof and hot metal bottles or ladles spotted under the cast house floor.

      Johnstown "E", "H", "L"; Lackawanna "C", "F", "G", "H", "J"; Sparrows Point "A", "B", "C", "D", "E", "F", "G", "H", "K"

   B. Slag pots spotted under a lean-to and hot metal bottles or ladles spotted under cast house floor.

      Bethlehem "C", Inland #1, #2, #4, #5, #6, U.S.S.-Edgar Thomson #1, 2, 3, 5, & 6

   C. Slag pots spotted under a lean-to and hot metal ladles spotted under a lean-to and cast house floor.

*Furnace has auxiliary slag pits
**Furnaces have auxiliary slag granulation

Inland #3

7. With slag pots and open cast house floor and:

   A. Slag pots spotted either under an extension of the cast house, a lean-to or under the cast house floor and:

      a. Hot metal bottles spotted under a lean-to.

         National Weirton #1

      b. Hot metal bottles spotted under cast house roof.

         Bethlehem "B", "D", "E"

      c. Hot metal bottles spotted under cast house roof and a lean-to.

         Republic Youngstown #1 & #3, J&L C-1

   B. Slag pots spotted under a completely separate roof and hot metal bottles under a lean-to.

      CF&I "A", "D", "E", "F"

II. Cast house crane runway aligned perpendicular to radius of the blast furnace proper over the iron trough.

1. With hard slag pits and solid cast house floor.

   A. Slag pits at opposite end of cast house from furnace proper and hot metal bottles spotted under an extension of cast house roof.

      Republic Cleveland #5, #6, Republic Chicago #1

   B. Slag pits adjacent to cast house and hot metal bottles spotted under cast house roof.

      Cyclops Corp. Portsmouth #1; Crucible #1

      a. Hot metal bottles spotted under lean-to attached to the main cast house .

         U.S.S. - Duquesne No. 1

2. With slag pots and:

   A. An open cast house floor, slag pots under a lean-to and hot metal bottles under the cast house roof .

      Interlake Toledo "A"*

*Furnace has auxiliary slag pits

B. A solid cast house floor, slag pots under the cast house roof and under an extension of the roof, hot metal bottles spotted under an extension of the cast house roof or a lean-to attached to the main cast house roof.

J&L Pittsburgh P-3*; U.S.S.-Duquesne No. 3; U.S.S.-Lorain Nos. 1,2 & 5

3. With slag granulation or pelletizing and solid cast house floor .

A. Hot metal bottles spotted under extension of cast house roof .

U.S.S.-Duquesne No. 4

III. Blast furnace without cast house crane.

1. With hard slag pits and solid cast house floor. Pits adjacent to and opposite from hot metal bottles spotted under a lean-to.

Republic Gadsden #1

2. With slag pots and solid cast house floor.

A. Slag pots and hot metal ladles spotted under lean-to.

W-P Steubenville #3, #4, #5; Armco Hamilton #2*

B. Slag pots spotted under cast house roof extension and hot metal ladles spotted under lean-to.

Armco Hamilton #1*

C. Slag pots spotted under cast house roof and an extension, hot metal bottles under a cast house roof extension.

J&L Pittsburgh P-6*, P-1*

D. Slag pots spotted under a lean-to and the hot metal bottles under the main roof in an arcade.

U.S.S. - Youngstown Nos. 2, 3, 4, &5

*Furnace has auxiliary slag pits

IV. Two blast furnaces with a common cast house - all with solid cast house floor and a cast house crane.

1. With slag pots spotted under lean-to and:

   A. hot metal bottles under a lean-to.

   National Granite City "A" & "B"; U.S.S.-Geneva Nos. 2&3

   B. Hot metal bottles under lean-to - no cast house crane.

   W-P Steubenville #1, & #2, Sharon #2 & #3

2. With slag pots spotted under an extension of the cast house and:

   Hot metal bottles under a lean-to

   J&L Aliquippa A-1, A-2, A-3 & A-4

3. With slag pots spotted under an extension of the cast house roof and under the cast house roof.

   Hot metal bottles under a lean-to.

   National Weirton #2 & #3

4. With slag granulating pits adjacent to the cast house and:

   Hot metal bottles under a lean-to.

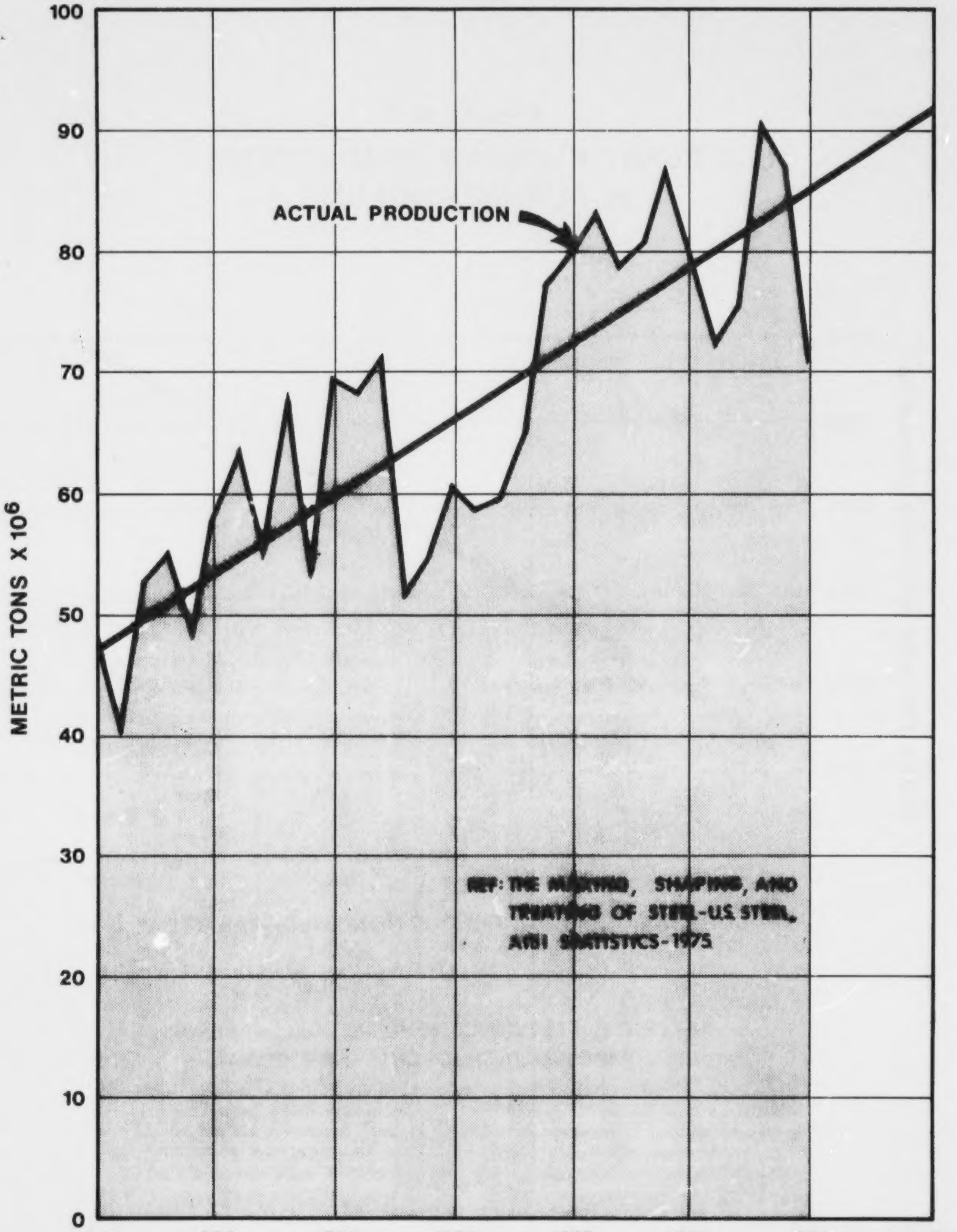
   W-P Monessen #1 & #2

IRON PRODUCTION STATISTICAL DATA

It is reasonable to predict that the trend of increasing iron production in the United States will continue based on history as plotted on Figure 4-6. The number of blast furnaces will decrease as larger furnaces replace two or more smaller production units. 500 million net tons of world-wide production capacity is anticipated in 1980, U.S. production, based on an economic up-turn, should total about 100 million tons or 20% of the world's output. Classification of existing furnaces is shown on Figures 4-7, 4-8, and Table 4-1 while Table 4-2 is a listing of standing basic iron blast furnaces for which the B.E.E./AISI questionnaire was completed.

Figure 4-6

IRON PRODUCTION IN U.S.A.

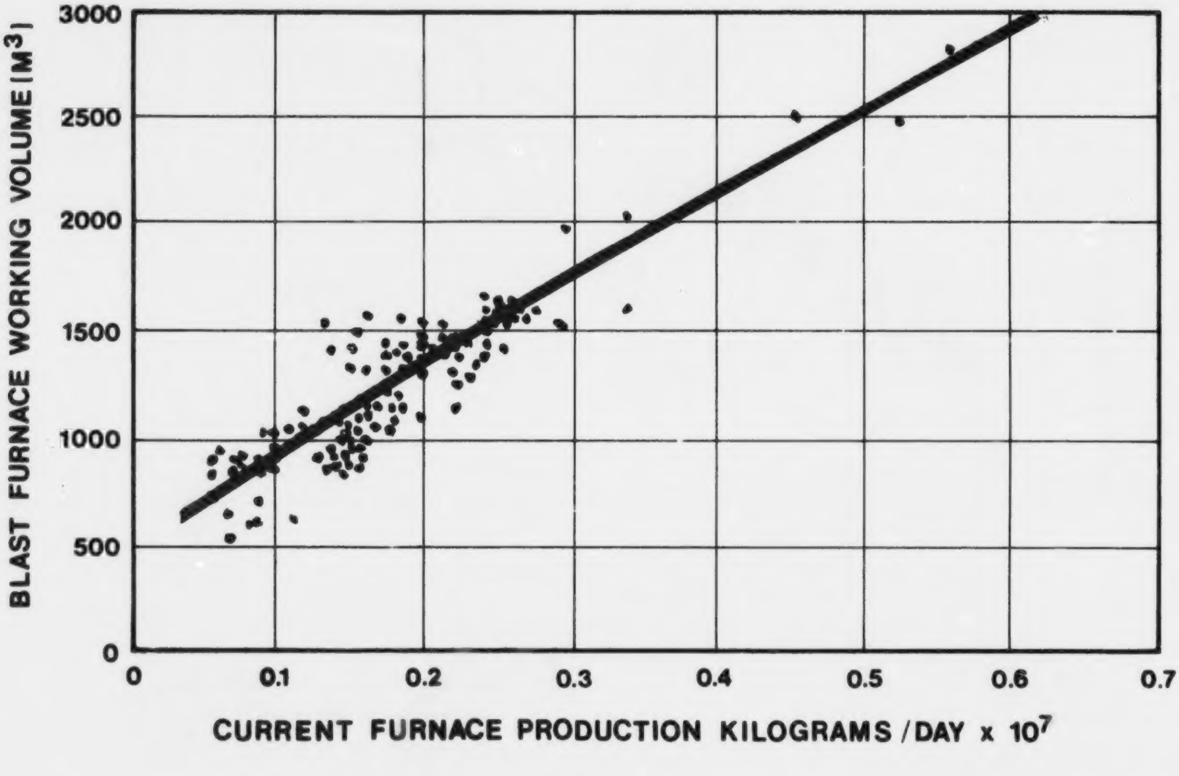


REF: THE MAKING, SHAPING, AND TREATING OF STEEL-U.S. STEEL, AISI STATISTICS-1975

BASIC IRON PRODUCTION-U.S.A.

Figure 4-7

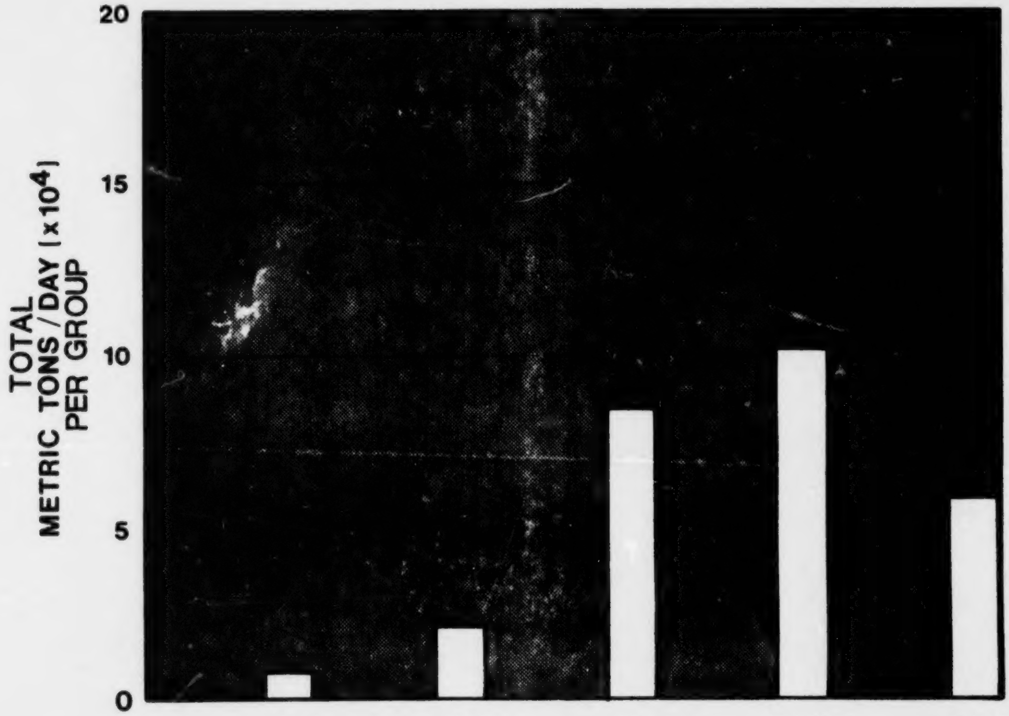
U.S. BLAST FURNACE PRODUCTION vs. FURNACE VOLUME



REF: B. E. E. STEEL QUESTIONNAIRE, SEE APPENDIX A, PAGES A-21 THROUGH A-24 FOR DATA

Figure 4-8

DOMESTIC BLAST FURNACES CLASSIFICATION BY SIZE AND AVERAGE PRODUCTION[1]



RANGE M.T./D./B.F.	635-1249	816-1618	726-2034	1270-2948	1588-5625
NO. B.F.	8	19	58	47	19
% NO. B.F.	5	13	38	31	13
GROUP PRODUCTION					
WORKING VOLUME RANGE (M^3)	421-700	701-840	841-1270	1271-1560	1561-2831
HEARTH DIA. RANGE (M)	4.6-6.8	6.0-7.1	5.9-8.5	7.9-9.1	7.8-12.2
GROUP NO.	1	2	3	4	5

(1) DATA FROM BEE/AISI QUESTIONNAIRE, SEE APPENDIX A, PAGES A-21 THROUGH A-24.

TABLE 4-1

BLAST FURNACE - CLASSIFICATION BY SIZE AND AVERAGE PRODUCTION(1)

Working Volume Cubic Meters	Average Hearth Dia. Meters	Average Daily Production(2) Metric Tons	No.
420 - 560	4.9	703	3
561 - 700	6.1	983	5
701 - 840	6.4	1260	19
841 - 990	7.0	1159	23
991 - 1130	7.7	1537	15
1131 - 1270	8.0	1699	20
1271 - 1420	8.3	2059	21
1421 - 1560	8.8	2278	26
1561 - 1700	8.8	2402	12
1701 - 1840	10.0	3734	1
1841 - 1980	9.8	2981	1
1981 - 2120	10.0	3713	2
2121 - 2260	-	-	0
2261 - 2400	-	-	0
2401 - 2540	11.1	4923	2
2541 - 2680	-	-	0
2681 - 4000	12.2	5625	1
		Total Reported Standing Blast Furnaces	151

(1) As reported in the BEE/AISI questionnaire, see Appendix A pages A-21 through A-24.

(2) Current daily production as reported on questionnaire.

TABLE 4-2

STANDING BASIC IRON BLAST FURNACES

REPORTED THROUGH B.E.E./AISI QUESTIONNAIRE(A)

	No. Furnaces	Reported Daily Production (tonnes)
Alan Wood Steel Company		
Swede Furnaces, Swedeland and Ivy Rock, Pennsylvania	2	1814
Armco Steel Corporation		
Ashland, Kentucky	2	6160
Houston, Texas	1(B)	-
Hamilton and Middletown, Ohio	3(C)	4512
Bethlehem Steel Corporation		
Burns Harbor, Indiana	2	9945
Bethlehem, Pennsylvania	4	8441
Sparrows Point, Maryland	10(D)	17930
Lackawanna, New York	5	9741
Johnstown, Pennsylvania	3(E)	5964
CF & I Steel Corporation		
Pueblo, Colorado	4	2902
Detroit Steel Corporation		
Portsmouth, Ohio	1	3220
Ford Motor Company		
Dearborn, Michigan	3	4027
Inland Steel Company		
Indiana Harbor, East Chicago, Illinois	8	15319

(A) Questionnaires dated Jan. through April 1976.
(B) Houston #1 reported inactive and without production values.
(C) Hamilton #2 reported inactive and without production values.
(D) Sparrows Point A,B,E,F,G,K reported as inactive.
(E) Johnstown "G" reported as inactive.

TABLE 4-2 (Cont-d)

	No. Furnaces	Reported Daily Production (tonnes)
Interlake Steel Corporation		
Chicago and Riverdale, Illinois	2	2698
Toledo, Ohio	2 (F)	862
Jones & Laughlin Steel Corp.		
Aliquippa, Pennsylvania	5 (G)	5760
Pittsburgh, Pennsylvania	1	2078
Cleveland, Ohio	2	4190
Kaiser Steel Corporation		
Fontana, California	4	7101
Lone Star Steel Company		
Lone Star, Texas	1	1633
McLouth Steel Corporation		
Trenton, Michigan	2	4852
National Steel Corporation		
Weirton, West Virginia	4	7710
Granite City, Ill.	2	4354
Buffalo, N.Y.	3	2245
Republic Steel Corporation		
Youngstown, Ohio	2	3672
Warren, Ohio	1	2358
Cleveland Ohio	4	7065
Buffalo, New York	2 (H)	1581
South Chicago, Illinois	1	2358
Gulfsteel, Gadsden, Ala.	2	2414

(F) Interlake, Toledo "A" inactive and without production values.

(G) J & L Aliquippa #A-1 and A-4 reported inactive and without production values.

(H) Republic Buffalo #1 reported inactive and without production values.

TABLE 4-2 (Cont-d)

	No. Furnaces	Reported Daily Production (tonnes)
Shenango, Inc.		
Shenango, Pennsylvania	1	1088
Steel Company of Canada	4	10,322
United States Steel Corporation		
Duquesne, Pennsylvania	4 (I)	5079
Edgar Thomson, Braddock, Pennsylvania	5	7471
Rankin, Pennsylvania	4	5938
Gary, Indiana	11 (J)	19609
South Chicago, Illinois	3	6676
Fairless, Fairless Hills, Pennsylvania	3	6848
Fairfield District, Jefferson County, Ala.	6	4875
Geneva, Utah	3 (K)	3582
National, McKeesport, Pa.	1	998
Lorain, Ohio	6 (L)	6984
Youngstown, Ohio	4 (M)	3135
Youngstown Sheet and Tube		
Campbell, Campbell, Ohio	4 (N)	2903
Indiana Harbor, East Chicago, Indiana	4 (O)	6018

(I) Duquesne # 1 reported as inactive and without production values.
(J) Gary #5 & #9 reported as inactive.
(K) Geneva #3 reported as inactive and without production values.
(L) Lorain #5 reported as inactive and without production values.
(M) Youngstown #4 reported as inactive and without production values.
(N) Campbell #1 & #2 reported as inactive and without production values.
(O) Indiana Harbor #1 & #2 reported as inactive and without production values.

Larger furnaces are either under construction or being considered at Fairfield and Gadsden, Ala., Sparrows Point, Md., and at two locations in Indiana. These furnaces will produce from 5000 to 8000 tons of hot metal per day and will replace smaller units now in existance.

Direct reduction processes will not significantly replace the blast furnace operations in the foreseeable future. Thus the blast furnace, in some modified form, will continue to be the basic producer of ferrous metal.

FUTURE OF IRONMAKING

The steel industry is faced with an increasing shortage of fuels which will soon necessitate increased recognition of the requirements for more efficient equipment. Foreign plants have achieved a substantially greater savings in energy usage than has the U.S. To effect the goals that must be realized in the not too distant future, the U.S. must replace a major portion of its out-dated equipment.

At some mills it may be practical to consider the replacement of several existing inefficient blast furnaces with a single large more efficient blast furnace with a demonstrated integrated emission control system. The industry has already shown its recognition of the efficiency of the larger blast furnaces by new expansions, including those that are underway or proposed at Sparrows Point, Md.; East Chicago, Ind.; Fairfield, Ala.; Gadsden, Ala. and Portage, Ind.

Direct Reduction

An alternative method which is being developed to produce basic iron is the direct reduction process. This method would eliminate cast house emissions. Situations which could accelerate the development of direct reduction are:

1. A shortage of coking coal
2. Availability of electric power at acceptable cost
3. A requirement for reduced operating capacities which is limited with the blast furnace.
4. Economical locally available ore or concentrate of unusual properties
5. Availability of labor at acceptable cost
6. Limited availability of capital

Essentially, any process that does not use the blast furnace for iron processing can be considered a direct reduction process. The use of a blast furnace is considered an indirect process because two or more steps are required to obtain low carbon iron, blast furnace and the B.O.F. With direct reduction, a single process will give low carbon iron.

A wide variety of equipment has been utilized in various direct reduction processes. The following is a partial list of equipment that has been utilized at one time or another:

Reverberatory Furnace
Stationary Vertical Retort
Concentric Vertical Shafts
Reciprocating Vertical Retort
Rotary Kiln
Tunnel Kiln
Travelling Grate
Hearth Furnace
Rabbled-Hearth Furnace
Sealed Canisters
Electric Arc Furnace
Electric Resistance Furnace
Electric Induction Furnace
Fluidized Beds

More than 300 direct reduction processes have been conceived, of which only a few have reached extensive pilot plant development or commercialization. There are four main categories of direct reduction processes:

1. Kilns

2. Shaft Furnaces

3. Fluidized Beds

4. Retorts

The kiln process primarily utilizes solid fuels such as coal and coke breeze, while the other processes use primarily gaseous reductants. Fluidized beds require finely sized iron ore materials and normally require briquetting of the reduced product.

The Midrex process is the most widely used of all the commercial direct reduction processes. The process is flexible with respect to both feed and fuel. The existing plants generally operate with natural gas, but it is claimed that the process could operate with any fuel including naphtha and gas from coal. The process achieves a metallization of between 92% to 96%.

Armco Research developed a direct reduction process which utilizes a vertical moving bed shaft furnace with a continuous counter-current flow of reducing gas. West Germany's Krupp Industrie - und Stahlbau has become a licensee of the Armco process. Krupp also has its own process which uses a rotary furnace.

In Italy, the Kinglov Metor process uses coal as the reducing agent in a shaft type furnace.

Lurgi obtained the R-N patents and world rights in 1964, and the technical expertise from both Stelco-Lurgi and the R-N developments have been pooled to form the Sl-Rn Process. Crushed coke is the reductant and is utilized in a rotary kiln.

The growth of the direct reduction process is expected to increase. The future growth is dependent on:

1. Future blast-furnace practice
2. Transporation
3. Geography
4. Future steelmaking practice
5. Availability and price of steel scrap
6. Existing capacity for pig iron.
7. The availability of natural or other suitable gas.

SECTION 5

CAST HOUSE EMISSIONS

PARTICULATE EMISSIONS FROM CAST HOUSES

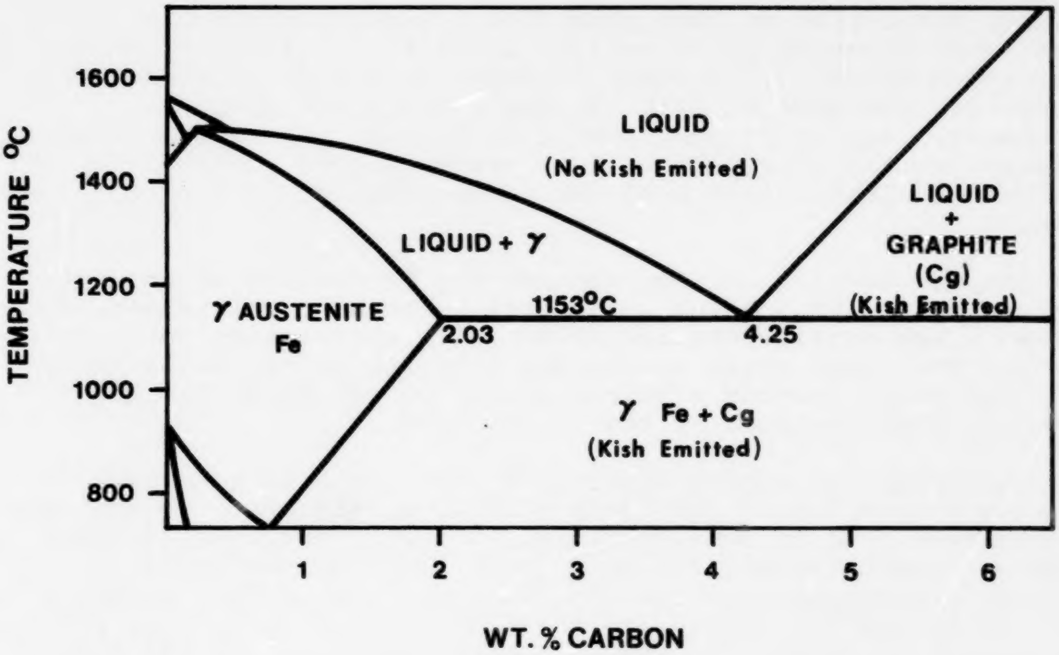
The primary source of fugitive emissions from casting is from the hot metal as it exits the blast furnace at the tap hole. This is primarily due to cooling of the hot metal as it comes in contact with the tap hole and encounters the atmosphere. A violent cast with excessive hot metal turbulence tends to create greater quantities of fume than does a smooth, controlled cast. A tap hole diameter of 40 mm (1.5 inches) is desirable and should not exceed 60 mm (2.5 inches) in order to assist in maintaining a controlled and smooth cast. However, drill bit problems frequently require oxygen lancing of the tap hole which tends to enlarge the tap hole. Also, long wearing, good quality clay will prevent tap hole enlargement during casting due to erosion from slag.

The tap hole in a given furnace may be drilled at an angle between 6° to 20° up from horizontal. The new, multiple-tap-hole furnaces are usually drilled at an angle approaching the lower slope. The lower angle lowers the iron trajectory while casting and thus would provide a better condition for close fitting emission capture hoods at the trough area.

The trough is a pool adjacent to the tap hole normally extending from 7.6 m. (25 feet) to 15.2 m. (50 feet) to the dam and skimmer. It is usually 0.9 m. (3 feet) to 1.2 m. (4 feet) wide and approximately 0.6 m.(2 feet) deep and serves as a holding pit to separate the hot metal and slag before allowing them to follow the runners to the ladles and slag pits or pots. The trough is lined with clay and coke breeze as are the runners for the molten metal and slag. Frequent castings necessitate considerable maintenance on troughs and runners and improved lining materials are constantly being evaluated. The runners must be thoroughly dried after each remaking to prevent violent reactions between the molten material and moisture, which result in the generation of larger than normal quantities of highly concentrated fume emissions.

The generation of fume from the runners is dependent on the pool areas exposed to the atmosphere and the metal temperature. As the metal cools, carbon emerges from the saturated solution as "kish", a form of graphitic carbon that is light and flaky (See Figure No. 5-1). "Kish" is readily air-borne, but probably it settles out short distances from its source. This is indicated in the DOFASCO information because carbon comprised only 3% by

Figure 5-1
CARBON–IRON DIAGRAM



REF: MAKING, SHAPING, AND TREATING
OF STEEL-BY U.S. STEEL

weight of the material found in the hoppers of control equipment on blast furnace cast house of #1 furnace. Iron oxides comprised 75% of the captured fume with small percentages of manganese, silicon oxides, and sulfates.

The hot metal cast from the blast furnace should be transported to the steel making facilities with minimum temperature losses. Two or more ladle cars, commonly known as bottles or torpedo cars, are used to accept the molten metal from the runner spouts. These cars may be located outside the cast house or in an arcade under the cast house floor. Capacities vary from 150 tonnes (165T) to 600 tonnes (660 T), the latter used only in some foreign plants. If the ladles are allowed to cool, the fume from pouring can become very dense due to rapid cooling of the hot metal.

Slag is either run into pits adjacent to the cast house or handled by open pots for conveying to a remote area for treatment.

ALTERNATIVE FILTERING EQUIPMENT FOR EMISSION CONTROL

While state and local opacity regulations may be met at some installations by venting the cast house directly to a stack without a control device, emissions could exceed applicable process weight regulations. Therefore, four major types of air pollution control devices are evaluated for possible application in the control of cast house emissions. The four categories are:

Mechanical Collectors

Wet Scrubbers

Electrostatic Precipitators

Fabric Filter Collectors

Mechanical Collectors

Mechanical collectors are inertial separators which operate by the principle of imparting centrifugal force to the particle to be removed from the gas stream. This force is produced by directing the gas in a circular path or effecting an abrupt change in direction.

Single-Cyclone Collector--

A cyclone is an inertial separator without moving parts. It separates particulate matter from a carrier gas by transforming the velocity of a inlet stream into a double vortex confined within the cyclone. In the double vortex the incoming gas spirals downward at the outside of the vortex and upward at the inside of the cyclone outlet. The particulates, because of their inertia, tend to move toward the outside wall where they are captured and discharged from the bottom of the cyclone.

Multi-Cyclone Separators--

A multi-cyclone separator consists of a number of small-diameter cyclones operating in parallel, having a common gas inlet and gas outlet. The flow pattern differs slightly from that of a normal cyclone, in that the gas, instead of entering the side, enters the top of the tube and has a swirling action imparted to it by stationary vanes located in the inlet of the tube.

Figure No. 5-2 illustrates typical mechanical collector particulate removal efficiency curves. The curves demonstrate that the particulate removal efficiency begins to drop when the particle size decreases below 15 microns.

Applicability to Cast House Emissions--

From observations of the cast house fumes and from the attached efficiency curves (Figure 5-2), mechanical type collectors could possibly meet the allowable emission rates of certain cast houses. Therefore, mechanical collectors could be considered as a viable solution to selective cast house emission problems. However, of the four devices mechanical collectors normally provide the lowest total particulate matter removal efficiency.

Wet Scrubbers

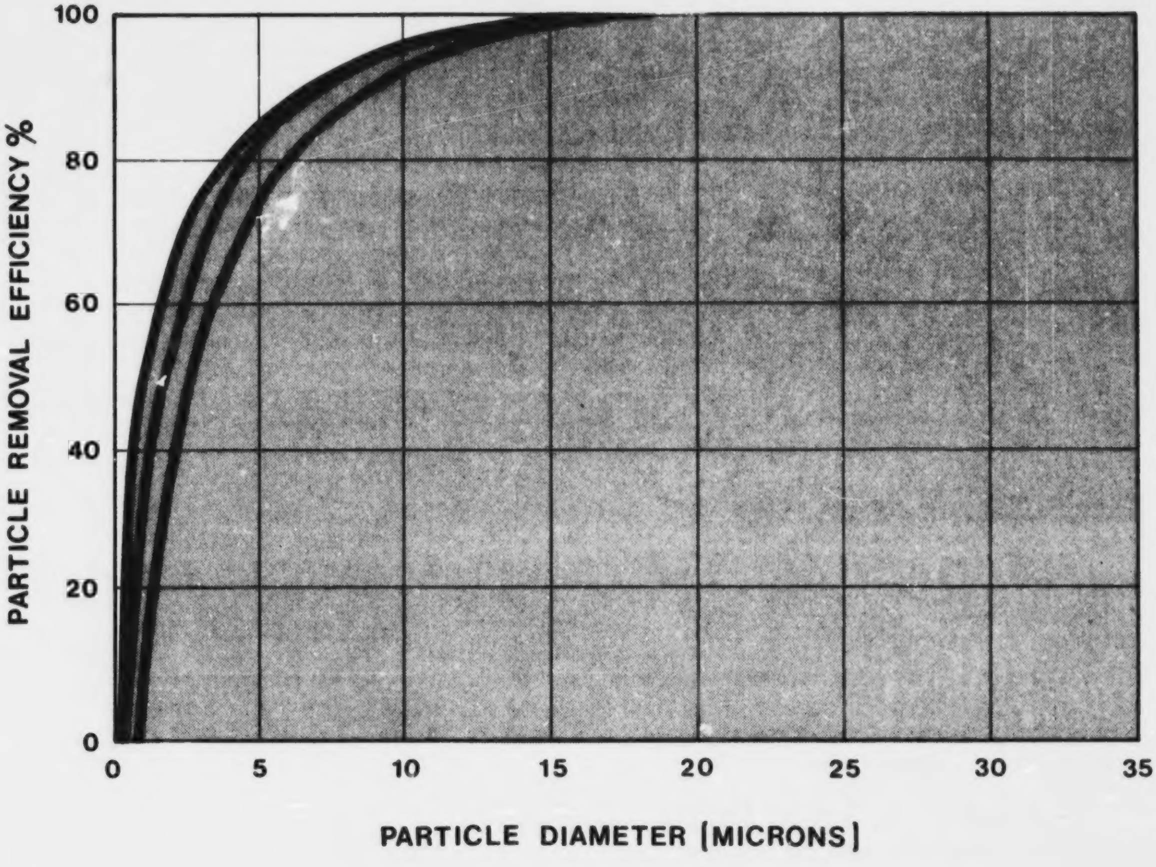
Wet scrubbers use a variety of methods to wet the particles in order to remove them from the gas stream. There is a wide range in the cost, the collection efficiency and the amount of power required.

The process of contacting a contaminated gas with a scrubbing liquid results in dissipation of mechanical energy in fluid turbulence and ultimately in heat. The power dissipated is termed the contacting power.

The principal mechanisms by which liquids may be used to remove aerosols from gas streams are as follows:

(1) Wetting of the particles by contact with a liquid droplet and

Figure 5-2
CYCLONE COLLECTION EFFICIENCY CURVES



(2) Impingement of wetted or unwetted particles on collecting surfaces followed by their removal from the surfaces by flushing with a liquid

The three basic types of wet scrubbers are tray scrubbers, spray cyclonic scrubbers and venturi scrubbers. Of the three, the venturi scrubber is the most effective and requires the least amount of maintenance. The primary function of the tray scrubber is the absorption of gaseous pollutants. The presence of particulate could have a tendency to plug the tray-type scrubber. The spray cyclonic scrubber relies on spin imparted to the gas at the inlet for disengagement of the solids from the scrubbing water. Maintenance requirements would be appreciable because of the abrasiveness of the particulate. The suspended particles in the recirculated liquor stream would eventually erode and possibly plug the water spray jets.

Applicability to Cast House Emissions--

The application of the venturi scrubber is a technically viable solution to the control of cast house emissions. It has an inherent advantage over all the other systems because it removes some gaseous pollutants. However, if water treatment facilities are inadequate and must be installed or expanded, a venturi scrubber system will require more installation space than is required by a precipitator or a baghouse. The venturi scrubber can only be recommended as a secondary alternative control device due to its high energy requirements (pressure drop) when compared to alternative control devices.

Electrostatic Precipitators

The electrostatic precipitation method of particle removal uses the forces acting on electrically charged particles in the presence of an electric field to separate solids from a gas stream. In the process, dust suspended in the gas is electrically charged and passes through an electric field where electrical forces cause the particles to migrate toward the collection surface. The dust is separated from the gas by the collection electrode.

Particles in a gas stream normally have a small inherent electric charge which is too small for effective electrostatic collection. Consequently, the precipitation process must provide a means for particle charging. In all commercial precipitator applications, the charging is accomplished by a high-voltage, direct-current corona.

Applicability to Cast House Emissions--

Although a precipitator could be designed to operate on cast house emissions, consistent effectiveness is doubtful due to the low resistivity of the carbon (kish) in the emissions. Carbon will accept the necessary electric charge, but carbon is also conductive and will readily give up its charge. As a result dust reentrainment can occur when the collecting plates of the dry type electrostatic precipitator are rapped.

In the wet electrostatic precipitator a water wash is used to dislodge the particulate matter from the collecting plates or tubes and to remove it from the precipitator in a water solution. The presence of water in the wet precipitator will reduce reentrainment somewhat because the water will entrap a portion of the carbon.

Because of resistivity problems and the fact that an electrostatic precipitator is normally the most costly of all control devices, it is not considered to be the best alternative for this application.

Fabric Filters

Fabric filters are very large vacuum cleaners with bags of various configurations made of porous fabrics which can withstand thermal, chemical and mechanical rigors of individual applications. The usual physical arrangement of fabric filter is in a series of cylindrical bags. Particles suspended in the gas stream impinge on and adhere to the filter medium and are removed from the gas stream. Frequently, this deposit of dust becomes the filtering medium for succeeding particles.

The use of an effective cloth cleaning mechanism allows operation of fabric filters at high air-to-cloth ratios while maintaining normal pressure drops. The most effective cloth cleaning mechanism for woven fabric type filters is the mechanical shaker. The mechanical design of the shaker must be such that all operating parts are located external to the gas stream for ease of inspection and maintenance. There are reports of high maintenance associated with shaker mechanisms and bag failure in other steel making operations which may warrant additional investigation as to the total suitability of this cleaning technique.

The air-to-cloth ratio on a fabric filter is defined as the cubic feet per minute of air passing through a square foot of filter fabric. It is readily apparent that this also is the filtration velocity in feet per minute through the fabric. The gross air-to-cloth ratio is calculated using the total amount of filter fabric in a collection system. The net air-to-cloth filter ratio is calculated based on removing a certain percentage of the fabric for cleaning and in some cases another percentage for maintenance. Sizing is generally done based on a net air-to-cloth ratio. However, for use on a partial cast house emission capture system this aspect becomes irrelevant since intermittent baghouse operation (operational only when casting) allows cleaning of the entire baghouse during periods of baghouse inactivity, which occurs between casts.

A baghouse could be designed to provide a maximum pressure drop across the cloth of 1493 Pascals (6" w.g.) at operating conditions. A pressure drop of approximately 498 Pascals (2" w.g.) through the inlet and outlet manifolds and damper valves must be added to the fabric pressure drop for a total baghouse resistance of 1991 Pascals (8" w.g.) Although many formulas have been developed to predict pressure drop, none have proved to be completely accurate. The mathematical model has yet to be developed that accurately predicts fabric filter performance, and the best projections come from operating experience on similar units.

Applicability to Cast House Emissions--

Because of relatively low energy requirements and high efficiency, fabric filters are considered to be the most suitable of all control devices for use with a cast house emission capture system. Additionally, the characteristics of the gas treated are compatible with this device.

Because the casting of hot metal is an intermittent activity, the baghouse for a partial control system would also operate intermittently, allowing the baghouse to be thoroughly cleaned between casts. For this application, a structural, non-compartmentalized, pressure-type unit that utilizes a shaker-type mechanism for cleaning either woven Orlon or Dacron fabric could be applied to keep capital and operating costs low. A non-compartmentalized baghouse would necessitate by-passing for maintenance activities that could not be completed during periods between casts.

For an application on a complete cast house evacuation system, a compartmentalized unit would be necessary if continuous cleaning was desired. This would be necessary if the baghouse were operating 24 hours a day for both cast house ventilation and emission control.

Ventilation of a system of close fitting covers and hoods within the cast house requires that attention be given to high gas temperature and possible spark carryover. A baghouse on such a system would require gas cooling techniques, such as dilution air or water evaporation, as well as spark drop-out chambers.

The baghouse installation on blast furnace No. 1 at Dominion Foundry and Steel, Ltd utilizes a structural intermittent baghouse which operates effectively in an air-to-cloth ratio range of from 2.5:1 to 3.5:1. Because of the relatively low concentrations of particulate matter suspected, air-to-cloth ratios in the order of 4:1 are not considered excessive.

EMISSION EVALUATION OF THE NUMBER ONE CAST HOUSE AT DOMINION FOUNDRIES AND STEEL, LIMITED

B.E.E. conducted a program to evaluate cast house emissions from a blast furnace located at DOMINION FOUNDRIES AND STEEL, LIMITED (DOFASCO) in Hamilton, Ontario, Canada. All testing was conducted in accordance with the procedures and specifications established by the EPA.

Testing was performed to determine the amount of cast house emissions upstream of the emission control device. Evaluated parameters were:

Gas Flow - ACFM and SCFM

Gas Temperature - °F

Moisture Content - Volume %

Particulate Emissions - Grains/DSCF and Lbs./Hr.

Particle Size Distribution - Andersen Inertial Impactor - Weight %.

Sulfur Trioxide Emissions - PPM by volume and Lbs./Hr.

Sulfur Dioxide Emissions - PPM by volume and Lbs./Hr.

Procedures

Field Sampling--

The emission testing program was conducted from August 24, 1976 through August 28, 1976, using the following methods of sampling:

1. Sample and traverse locations were determined as per Method One of the Federal Register, Volume 36, Number 247, December 23, 1971, appropriately amended.
2. Gas flow, temperature, and static pressure measurements were made as per Method Two of the same Federal Register.
3. Moisture content sampling was conducted by Method Four.

4. Particulate sampling followed Method Five of the same Register.

5. The particle size distributions were performed using an Andersen Model 2000 inertial impactor according to Andersen specifications.

6. Sulfur trioxide and sulfur dioxide sampling was conducted simultaneously with the particulate sampling program by substituting isopropanol and hydrogen peroxide in the impingers.

All methods are outlined on pages C-1 through C-7 in Appendix C.

Equipment Calibration--

In accordance with the accepted procedures published by the EPA, all gas volume metering equipment, temperature measuring equipment, and flow rate metering equipment had been calibrated within 60 days of the actual test dates. Calibration data and the applied methodology are contained in Appendix C, pages C-23 through C-27.

Analytical Methods--

All particulate filters and Andersen plates were tared and weighed by B.E.E. personnel in DOFASCO'S on site laboratory. The remaining samples were returned to B.E.E. LABORATORIES, INC., of PLYMOUTH MEETING, PENNSYLVANIA for analysis. Refer to Appendix C, pages C-41 and C-42 for a detailed description of the methodology used to analyze the samples.

Calculations--

All gas flow, moisture content, particulate, and sulfur oxides calculations were performed by a computer. Raw data generated from these parameters were introduced into the equations of Methods Two through Five and Method Eight of the Federal Register. Particle size distribution data reduction was accomplished by using the three curves presented in the Andersen operations manual. Appendix C, pages C-28 through C-32 lists all equations used.

Summary of Results

Particulate/Moisture and Sulfur Oxides Testing--

A detailed listing of all evaluated parameters of the particulate, moisture, and sulfur oxides testing program is presented in Appendix C, pages C-35 through C-40. A tabulation of pertinent results appear in Tables 5-1 and 5-2. Note that the

TABLE 5-1

PARTICULATE SAMPLING RESULTS

Run Number	Cast Number	Damper Setting	Concentration KG/M^3	Concentration (gr/DSCF)	Emission Rate KG/HR	Emission Rate (lbs./hr.)
1*	3475	100%	0.0016	0.5623	635	(1399.4)
2	3480	100%	0.0005	0.1844	215	(476.1)
3	3481	100%	0.0003	0.1001	118	(260.3)
4	3482	40%	0.0005	0.1670	119	(262.2)
5	3487	40%	0.0007	0.2322	176	(390.3)
6**	3488	70%	0.0006	0.2056	241	(531.3)
7	3489	70%	0.0004	0.1284	149	(328.7)
8**	3492	70%	0.0002	0.0535	57	(126.3)
9	3493	70%	0.0004	0.1230	122	(268.0)
2&3 Avg		100%	0.0004	0.1422	175	(386.2)
4&5 Avg		40%	0.0006	0.1996	148	(326.2)
7&9 Avg		70%	0.0003	0.1257	135	(298.4)

* High rate of emissions during this run were due to weight of gasket particles caused by excessive temperatures in testing equipment. Subsequent testing conditions were altered to eliminate problem.

** Testing results for these runs have been affected by upset process conditions and are considered unreliable.

three exhaust conditions sampled are designated by 100, 70 and 40 percent. These three conditions were used to develop the exhaust CFM vs. Particulate Emission data. At the 40% damper setting the cast house atmosphere was too concentrated with fumes to provide satisfactory working conditions.

TABLE 5-2

SULFUR OXIDES SAMPLING RESULTS*

Run	Damper		Sulfur Trioxide			Sulfur Dioxide	
Number	Setting	(ppm)	Kg/sec.	lbs/hr	(ppm)	Kg/sec.	lbs/hr
1	100%	0.19	0.0052	0.69	41.0	0.9021	118.7
2	100%	0.23	0.0066	0.87	51.8	1.1818	155.5
3	100%	0.48	0.0139	1.83	2.0**	0.0464	6.1**
4	40%	17.4	0.3025	39.8	57.6	0.8003	105.3
5	40%	8.7	0.1603	21.1	60.3	0.8968	118.0
6	70%	1.2	0.0339	4.46	47.3	1.0815	142.3
7	70%	0.77	0.218	2.87	32.5	0.7364	96.9
8	70%	1.5	0.0404	5.32	48.0	1.0017	131.8
9	70%	1.2	0.0287	3.78	3.1**	0.0616	8.1**
1-2 Avg	100%	0.30	0.0086	1.13	46.4	1.0420	137.1
4-5 Avg	40%	13.0	0.2318	30.5	59.0	0.0882	11.6
6-8 Avg	70%	1.17	0.0312	4.11	42.6	0.9401	123.7

*Test data for reference only.
**Unexplainable low values.

Table 5-3 summarizes and relates the valid particulate test data to process data. Pertinent process data are presented in Appendix C, pages C-51 through C-58.

DOFASCO Conducted Emission Factor Evaluation Program--

Between August 30, 1976 and November 19, 1976 DOFASCO conducted an independent emission factor evaluation program on its No. 1 blast furnace cast house. This program related the weight of particulate matter captured by the cast house control system baghouse to the tons of hot metal cast for 14, two and three-day periods. Table 5-4 presents the results of the program. The emission factor values obtained by this method are in the same range as the values obtained from the stack sampling program.

TABLE 5-3

AVERAGE PARTICULATE RESULTS AS RELATED TO PROCESS DATA

Test Run No.	Cast No.	Cast House Evacuation Rate NM^{3}M C^o	Cast House Evacuation Rate ACFM @ ^{o}F	Particulate Emissions KG/HR	Particulate Emissions LBS/HR	Metric Tons Metal Cast	Tons Hot Metal Cast	Duration of Cast Minutes	Emission Factor KG/metric THM	Emission Factor lbs/ THM	% Open Fan Setting of C.H. Emission Control System	Cast(1) House Temp. ^{o}F	Visible Emissions Escaping Cast House
2	3480	9776 60	345,200 @ 140	216	476	236	260	30	0.46	0.92	100%	-	None (3)
3(2)	3481	9796 53	345,900 @ 128	118	260	267	294	44	0.32	0.65	100%	-	None (3)
Average at High Rate		9786	345,500						0.39	0.78		36^{o}C (98^{o}F)	
7	3489	9759 62	344,600 @ 144	149	329	326	359	33	0.25	0.50	70%	-	None (3)
9	3493	9068 57	320,200 @ 135	122	268	257	283	30	0.23	0.47	70%	-	None (3)
Average at Medium Rate		9413	332,400						0.24	0.48		38^{o}C (103^{o}F)	
4	3482	6534 66	230,700 @ 150	119	262	237	262	36	0.30	0.60	40%	-	Yes
5	3487	7142 71	252,200 @ 159	177	390	275	303	36	0.38	0.77	40%	-	Yes
Average at Low Rate		6839	241,500						0.34	0.68		44^{o}C (113^{o}F)	

(1) Ambient temperature inside cast house at the point identified as No. 10 in Figure 5-3

(2) During this test run an opacity observation was conducted on the baghouse by-pass stack. The smoke density value obtained was 23.1%, see Appendix C, page C-17 for data sheet.

(3) While no noticeable visible emissions are reported, occassional WISPS were noticed emanating from the area of the cast house that abuts the slag pits and were suspected of originating from the pits external of the cast house.

TABLE 5-4 (1)

DOFASCO Conducted Emission Factor Evaluation Program On No. 1 Blast Furnace Cast House Control System

Period	Lbs. of Dust Total KG	Lbs. of Dust Total Lbs	Lbs. of Dust Daily Avg. KG	Lbs. of Dust Daily Avg. Lbs	Tons of Hot Metal Cast Tonne	Tons of Hot Metal Cast Tons	Emission Factor KG/Tonne	Emission Factor Lbs/Ton
Aug. 30-Sept. 3	2259	4980	564	1245	6688	7373.6	.338	.675
Sept. 24-Sept. 27	2468	5440	822	1813	5852	6451.2	.422	.843
Sept. 27-Oct. 1	1778	3920	445	980	7365	8119.4	.241	.482
Oct. 12-Oct. 15	2250	4960	750	1653	6184	6817.9	.363	.727
Oct. 15-Oct. 18	1669	3680	557	1227	6366	7017.2	.262	.524
Oct. 18-Oct. 22	2186	4820	547	1205	8334	9187.0	.261	.523
Oct. 22-Oct. 25	1687	3720	562	1240	6174	6806	.273	.546
Oct. 25-Oct. 29	1642	3620	411	905	7281	8026.0	.226	.451
Oct. 29-Nov. 1	1061	2340	353	780	6487	7151.4	.163	.327
Nov. 1-Nov. 5	1805	3980	451	995	8853	9759	.203	.407
Nov. 5-Nov. 9	2341	5160	585	1290	8443	9307.3	.277	.554
Nov. 9-Nov. 12	1052	2320	351	773	5943	6551.5	.177	.354
Nov. 12-Nov. 15	1143	2520	381	840	6487	7151.4	.176	.352
Nov. 15-Nov. 19	1569	3460	392	865	6004	6618.3	.261	.522
Average Emission Factor							.26 KG/Tonne of hot metal	.52 lbs./ of hot meta

(1) Data collected by DOFASCO and transmitted to Betz Environmental Engineers, Inc. through the AISI by letter of December 6, 1976.

The data in Table 5-3 are grouped according to "damper setting" which does not correlate well with cast house evacuation rates. The damper setting variation of 30% between the high and medium rates resulted in a maximum evacuation rate variation of only 7.4% between test no. 3 at 9796 NM^3 per minute and test no. 9 at 9068 NM^3 per minute. Grouping tests nos. 2,3,7 and 9 together results in a calculated average emission factor of 0.32 kilograms per metric ton of hot metal (0.63 lbs. per ton). It is likely that the test results are accurate only to the nearest tenth which gives an emission factor of 0.3 kilograms per metric ton (0.6 lbs. per ton).

The weight results obtained by DOFASCO (Table 5-4) average - 0.26 Kg/tonne hot metal (0.52 lbs./THM) over the three month period. This emission factor should be considered reliable for DOFASCO B.F. No. 1 since the quantities of material weighed allows error factors that would not greatly affect the rate of emissions. It also includes a spread of time and casting rates over hundreds of casts which balance out the highs and lows to provide an average result.

Particle Size Distribution Results--

A particle size classification was performed on the bypass stack at the No. 1 blast furnace at DOFASCO. An Andersen In-Stack sampler, which is basically a cascade impactor, was used to classify the sizes of particulate material in the stack. The tests were conducted simultaneous to the particulate tests at a point 90° from the particulate sampling point. A visual inspection of the plates after testing indicated that fractionation of the larger sized particulate probably occurred. The Kish (graphite) material is the large type particle which should have been collected on the very first plate of the collector. Because approximately 60% of the total material captured in the particulate tests was removed from the nozzle, probe and front half of the filter holder, the expected particle size test data should show significant quantities of large size (greater than 7 microns) particulate matter. A cyclone collector is not provided by Andersen ahead of the first plate to collect the larger particles (over 7 micron) but it is felt by B.E.E. that this cyclone is needed to remove the larger size particles. Therefore, it was decided that these data are not reliable and could be misleading and consequently are not included in this report.

Particulate Matter Characterization--

The Industrial Environmental Research Laboratory of EPA arranged for spark source mass spectrometric analysis of the captured particulate matter. This work was conducted by Northrop Services Inc. Research Triangle Park, N.C.

The results of elemental analysis of the EPA Method 5 filters and the particle size distribution sampling train filters are contained in Appendix C, pages C-59 through C-72, and identified as report no. SS7704. Due to high levels of several elements in the filters themselves, full characterization of the samples was not possible.

EPA obtained from DOFASCO a sample of particulate matter from the baghouse hoppers for elemental analysis. The results of this analysis appears in Appendix C, pages C-73 through C-79 and is identified as report no. SS7705. In addition to elemental analysis, a particle density of 3.69 grams per cubic centimeter was determined for this sample using a helium pycnometer.

Cast House Atmosphere--

The data in Table 5-5 were recorded to determine the effect of reducing the evacuation volumes on interior cast house ambient conditions. At the 40% open setting of the fan damper the cast house atmosphere was very dense with fume. At both the 70% and 100% settings the cast house had adequate ventilation to satisfy the operators. The attached Figure 5-3 plots the personnel sampler locations inside the cast house. Figure 5-4 is a graphical representation of particulate matter concentration values.

Dust samplers were attached to workers on the cast house floor to collect dust above and below 5 microns from the cast house atmosphere during blast furnace casting. Employees wearing the samplers moved about the cast house in a normal manner. Samples were collected during two (2) cast for each of 70% and 100% fan damper setting conditions. The samplers used were "Bendix Micronair Gravimetric" designed for industrial atmospheres utilizing battery-powered piston pump to Sample 1.6 liters per minute. A cyclone was used to remove all particulate matter larger than 5 microns while particles less then 5 micron were captured on an 0.8 micron pore size Millipore filter in a plastic cassett. The cyclone catches were weighed on site by DOFASCO Laboratory personnel. The filters were returned to B.E.E. LABORATORIES, INC., for analysis.

Temperatures were measured in the cast house during casting with a mercury thermometer. SO_2 concentrations were obtained during casting using MSA indicator tubes at locations 8 and 10 as shown on Figure 5-3. These locations were the nearest to the hot metal allowed by the DOFASCO Safety Department.

CAST HOUSE EMISSION FACTORS

Particulate emission factors have been estimated at six locations as follows:

TABLE 5-5

TEMPERATURES, VELOCITIES AND SO_2 CONCENTRATIONS INSIDE CAST HOUSE

	Temperatures(1) °C (°F)			Velocity(2) MPS (FPM)			SO_2(3) MG/M³ (PPM)		
Locations*	40% Open	70% Open	100% Open	40% Open	70% Open	100% Open	40% Open	70% Open	100% Open
1				2.5(500)	4.0(800)	6.0(1200)			
2				1.5(300)	3.5(700)	5.0(1000)			
3				1.5(300)	3.5(700)	5.0(1000)			
4				1.3(250)	3.0(600)	4.0(800)			
5				1.3(250)	3.0(600)	4.0(800)			
6				- -	- -	- -			
7				0 0	0 0	0 0			
8	40(104)	36(98)	33(92)	0.5(100)	1.0(200)	1.5(300)	48(40)	24(20)	6(5)
9				0.8(150)	1.5(300)	2.0(400)			
10	44(111)	38(101)	36(98)	1.5(250)	2.0(400)	3.0(600)	60(50)	36(30)	6(5)
11				1.5(250)	2.0(400)	3.0(600)			
12				1.75(350)	3.0(600)	4.0(800)			

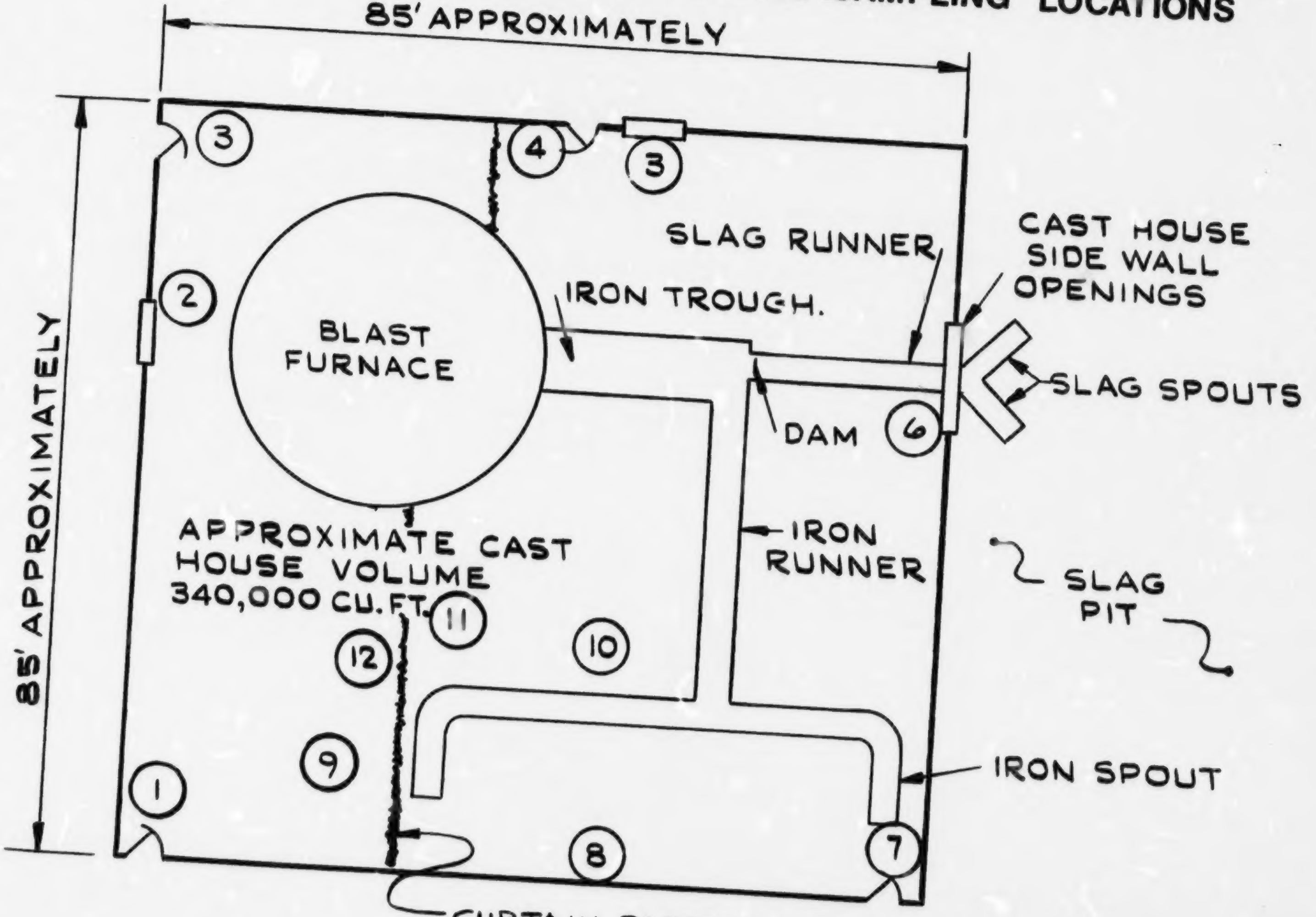
Conditions Inside Cast House
Figure 5-3 Shows Location of 12 Points

(1) Temperature values were obtained using a mercury thermometer.

(2) Velocity values were obtained using a hot wire anemometer.

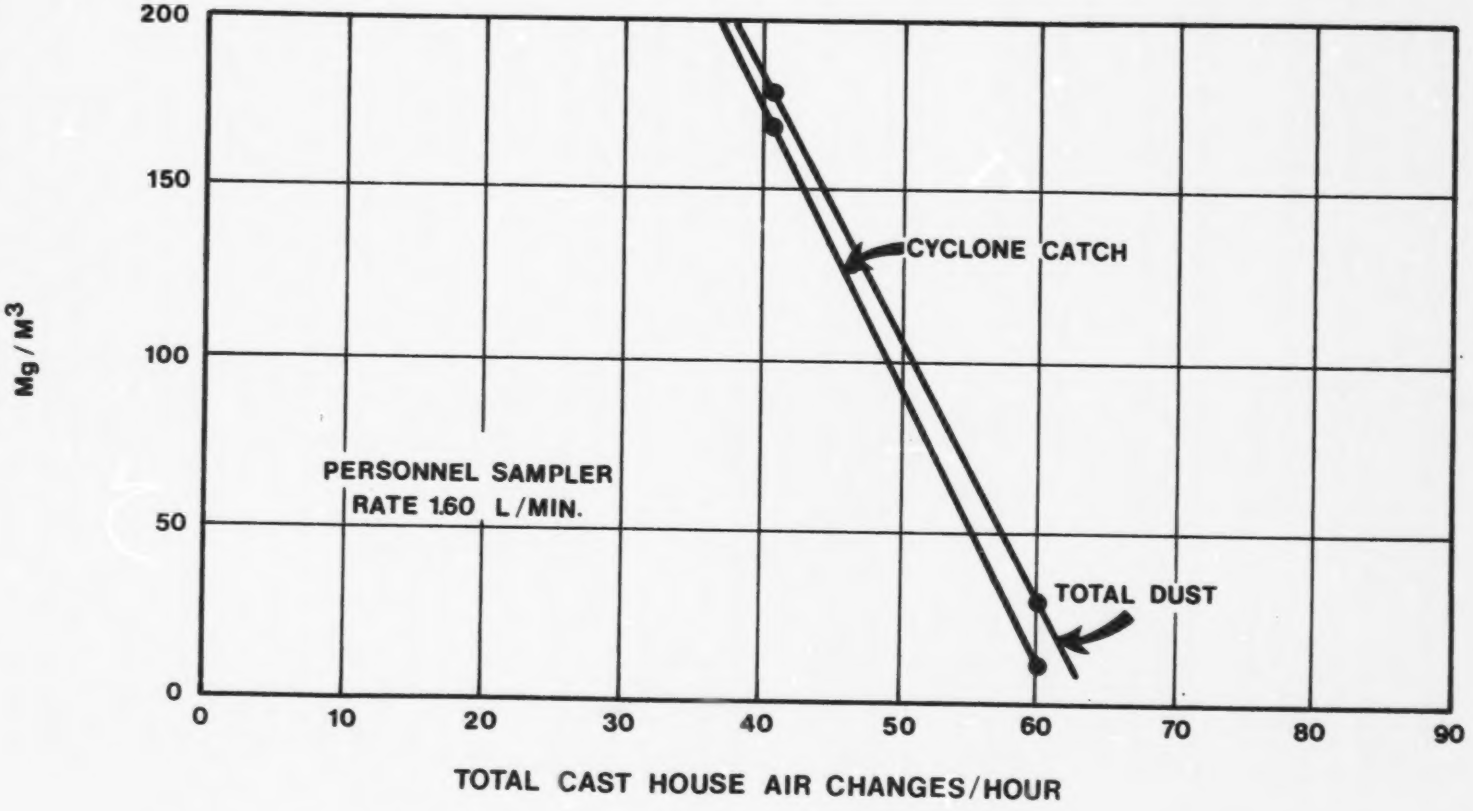
(3) SO_2 values were obtained using color indicator tubes which may be in the 75% to 100% accuracy range.

Figure 5-3
FLOOR PLAN REPRESENTATIVE OF DOFASCO BLAST FURNACE No.1 CAST HOUSE SHOWING PERSONNEL SAMPLING LOCATIONS


85' APPROXIMATELY
85' APPROXIMATELY
3
4
3
2
BLAST FURNACE
SLAG RUNNER
IRON TROUGH.
CAST HOUSE SIDE WALL OPENINGS
SLAG SPOUTS
DAM
6
APPROXIMATE CAST HOUSE VOLUME 340,000 CU. FT.
IRON RUNNER
SLAG PIT
11
10
12
9
1
8
7
IRON SPOUT

CURTAIN PARTITION NOT CONSIDERED IN CAST HOUSE VOLUME OR AIR CHANGE CALCULATIONS.
IN ALL CASES TOTAL CAST HOUSE VOLUME IS USED

Figure 5-4
DOFASCO No. 1
CAST HOUSE INTERNAL CONCENTRATION
OF PARTICULATE MATTER VS.
TOTAL CAST HOUSE AIR CHANGES



60 CHANGES : 9630 M^3/MIN. (340,000 CFM)
44 CHANGES : 7080 M^3/MIN. (250,000 CFM)

1. DOFASCO blast furnace No. 1 fumes are controlled by a total cast house evacuation system with a cloth collector filtering 300,000 CFM. From hopper weight collections, the loading has been determined as averaging 0.26 kilograms per metric ton (0.52 lbs/ton) of hot metal. Values were obtained from DOFASCO Environmental Department.

2. The average test weight for DOFASCO blast furnace No. 1 over four casts was 0.3 Kg per tonne of hot metal (0.6 lbs per ton). Tests were conducted by B.E.E. using EPA sampling methods.

3. Bethlehem Sparrows Point "J" furnace fume was measured by high volume samplers at the building roof monitor. Average collection was 0.15 kilograms per metric ton (0.3 lb/ton) of hot metal.

4. The C.F.&I cast house emissions were measured by time lapse photography and determined to be 0.125 kilograms per metric ton (0.25 lb/ton) of hot metal. Testing was conducted by Celesco Industries (report number 156).

5. Bethlehem Steel Corporation's Johnstown "E" Blast Furnace, normally a ferromanganese furnace, is the only blast furnace cast house in the United States employing an emission control system. The system captures casting emissions by totally evacuating the cast house at a nominal rate of 189 cubic meters per second (400,000 CFM) and filters out particulate matter with a baghouse.

   During the period from October 6, 1976 to November 10, 1976 the Johnstown "E" Blast Furnace emission control system, while temporarily producing basic iron, was sampled by Bethlehem Steel personnel for particulate matter. Each test consisted of sampling with a standard EPA type sampling train for the duration of one cast. Sampling was conducted in the 3.048 meter (10 foot) diameter baghouse inlet duct (prior to the fan). A preliminary twelve-point traverse was conducted before each test. Testing commenced at the start of metal flow from the iron notch. The maximum test duration was 36 minutes which consisted of sampling for three minutes at each of the twelve sample points. Those tests lasting less than 36 minutes were completed upon shut-in of the taphole and included only those test points sampled at that time. There was no reported estimate of system capture efficiency while the tests were being conducted. During the program the cast house evacuation rate was varied from 76 to 220 dry normal cubic meters per second (160,100 to 466,700 DSCFM) which is equivalent to 29 to

85 air changes per hour based upon an approximate cast house volume of 9300 cubic meters. The average particulate matter emission factor for the 19 test runs was 0.11 kilograms per metric ton of hot metal (0.22 lbs. per ton) for the combined front-half and back-half catches of the EPA sampling train and 0.10 kilograms per metric ton of hot metal (0.20 lbs. per ton) for the front-half catch only. See Appendix D, page D-1 for a table of Particulate Emissions Test Results.

6. Bethlehem Steel Corporation conducted emission tests during the weeks of September 13 and September 20, 1976, on an experimental emission control system it installed to capture the emissions which evolve from the taphole and trough during casting at their Bethlehem Plant, Blast Furnace "E." See Section 6 for a description of this system.

Tests were conducted under three different experimental conditions, as follows:

A. The "Original", unsecured curtain arrangement with the fan exhaust rate at approximately 42.5 actual cubic meters per second (90,000 ACFM).

B. The curtains removed with the fan exhaust rate at full capacity, approximately 143.5 actual cubic meters per second (304,000 ACFM).

C. The curtains weighted and secured. The fan exhaust was set at approximately 75 actual cubic meters per second (159,000 ACFM) which appeared to be the highest flow rate which could be used without danger of imploding the curtains.

Each emission test consisted of two individual traverses; one traverse was conducted on the horizontal axis of the exhaust duct and the other traverse was conducted simultaneously on the vertical axis of the duct. Sampling was commenced when the drill began to open the taphole; sampling was terminated within 5 minutes after the mud gun closed the taphole.

A summary of the data collected during the test program is presented in tabular form in Appendix D. Table I on page D-2 presents the results of the sampling conducted on the horizontal axis of the exhaust duct; Table II on page D-3 presents the results of the sampling conducted on the vertical axis of the exhaust duct; Table III on page D-4 presents the average of the corresponding values given in Table I and Table II. These average values in Table III were reported by Bethlehem Steel Corporation as the overall test results and are summarized as follows:

EXPERIMENTAL CONDITION	EMISSION FACTOR Kilograms per Metric Ton (pounds per ton) Front-half	Back-half	Total
"A"	0.05 (0.10)	0.025 (0.05)	0.075 (0.15)
"B"	0.13 (0.26)	0.08 (0.16)	0.21 (0.42)
"C"	0.125 (0.25)	0.02 (0.04)	0.145 (0.29)

Tests EBF-1 through EBF-3 were conducted under condition "A", Tests EBF-5 through EBF-7 were conducted under condition "B" and tests EBF-9 through EBF-11 were conducted under condition "C." Tests EBF-4, EBF-8 and EBF-12 were not reported by Bethlehem Steel Corporation because a standard particulate emission test was conducted only on the horizontal axis of the exhaust duct; simultaneous samples collected on the vertical axis of the duct were taken with an Anderson sampler in an attempt to collect particle size distribution data. Because of an extremely large isokinetic variation in the Anderson sampler tests, the results were considered questionable by Bethlehem Steel Corporation and consequently were not reported.

Emission tests were conducted in accordance with EPA Method 5. The impinger catch was evaporated to dryness and the residue reported as the back-half catch. Bethlehem Steel Corporation considers the most appropriate index of the relative capture efficiency of the system under the three test conditions as particulate measured by the front-half of the sampling train. The front-half particulate catch is not subject to the uncertainties which are inherent in the back-half of the EPA sampling train according to Behtlehem. An example of the uncertainties which can be associated with the back-half of the sampling train is shown by a comparison of the back-half catch measured on the horizontal axis of the exhaust duct with that measured on the vertical axis of the exhaust duct for tests EBF6. The tests conducted on the horizontal duct axis measured

> 0.128 kilograms per metric ton (0.256 lb. per ton) and 0.144 kilograms per metric ton (0.288 lb. per ton) for tests EBF-5 and EBF-6, respectively, whereas the tests conducted on the vertical duct axis measured 0.05 kilograms per metric ton (0.10 lb. per ton) and 0.045 kilograms per metric ton (0.09 lb. per ton). The back half samples were discarded and consequently it was not possible to analyze the residue to determine its chemical composition.

The average emission factor obtained during the DOFASCO NO. 1 Blast Furnace cast house emission testing program of 0.3 kilograms per metric ton of hot metal (0.6 lbs. per ton) and the 0.1 kilograms per metric ton (0.2 lbs. per ton) emission factor obtained at Bethlehem Steel Corp., Johnstown Blast Furnace "E" while producing basic iron represent the range of credible emission factor data. Based upon B.E.E. observations of the casting of 16 United States blast furnaces representing 7 domestic steel companies, it is felt that the casting operations at the DOFASCO NO. 1 Blast Furnace generates above normal fume quantities. Until additional emission factor data is obtained, the range of 0.1 to 0.3 kilograms per metric ton (0.2 to 0.6 lbs. per ton) should be used. It is B.E.E.'s judgement that a single emission factor for all domestic operations is not valid and that the observed differences in the levels of fume generated is due to variations in operating practices and materials used in the blast furnace and cast house.

POLLUTION FROM POWER HOUSE CAUSED BY CONTROL OF EMISSIONS FROM CAST HOUSE

Figures 5-5, 5-6 and 5-7 graphically depict estimated emissions from power houses which utilize various fuels and which supply electrical energy to operate a blast furnace cast house which has total evacuation capture system for emission control. Figure 5-5 is based upon a capture system designed to provide 50 cast house volume air changes per hour, while Figures 5-6 and 5-7 are based 60 and 70 cast house volume air changes per hour, respectively. Figure 5-8 charts particulate emissions from cast houses using the emission factor range of 0.1 to 0.3 kilograms per metric ton of hot metal cast (0.2 to 0.6 lbs. per ton).

The four conditions or curves on Figures 5-5, 5-6 and 5-7 relate power house emissions with the fuel utilization at the power house. These figures consider particulate matter, sulfur dioxide, and nitrogen oxide emissions from the power house and are based on complying with EPA new source performance standards (NSPS). Consequently, a power generating source which does not meet these emission limits whether it is a public utility or the steel mill's own power house would generate emissions greater than those presented in these figures.

Figure 5-5

POWER HOUSE EMISSIONS CAUSED BY TOTAL EVACUATION OF CAST HOUSE

50 CAST HOUSE AIR CHANGES PER HOUR

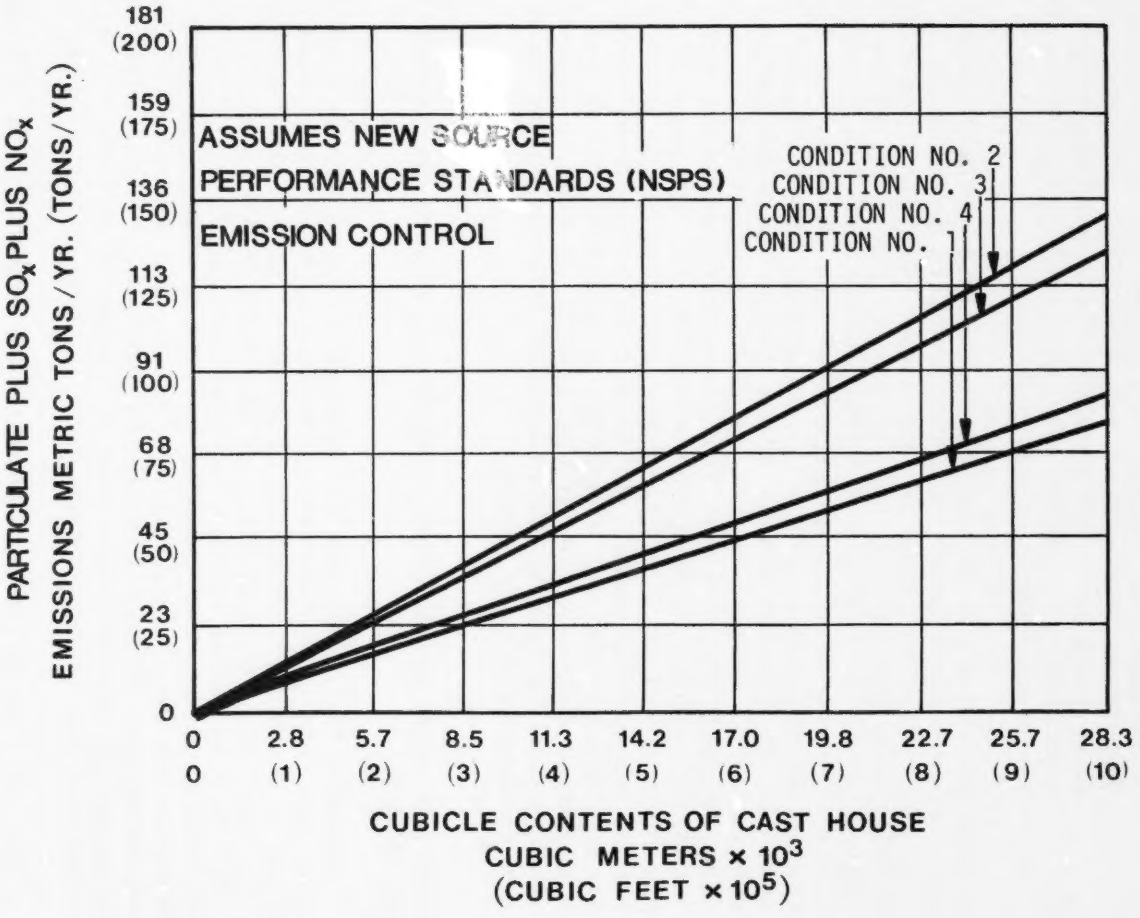


Figure 5-6
POWER HOUSE EMISSIONS CAUSED BY TOTAL EVACUATION OF CAST HOUSE
60 CAST HOUSE AIR CHANGES PER HOUR

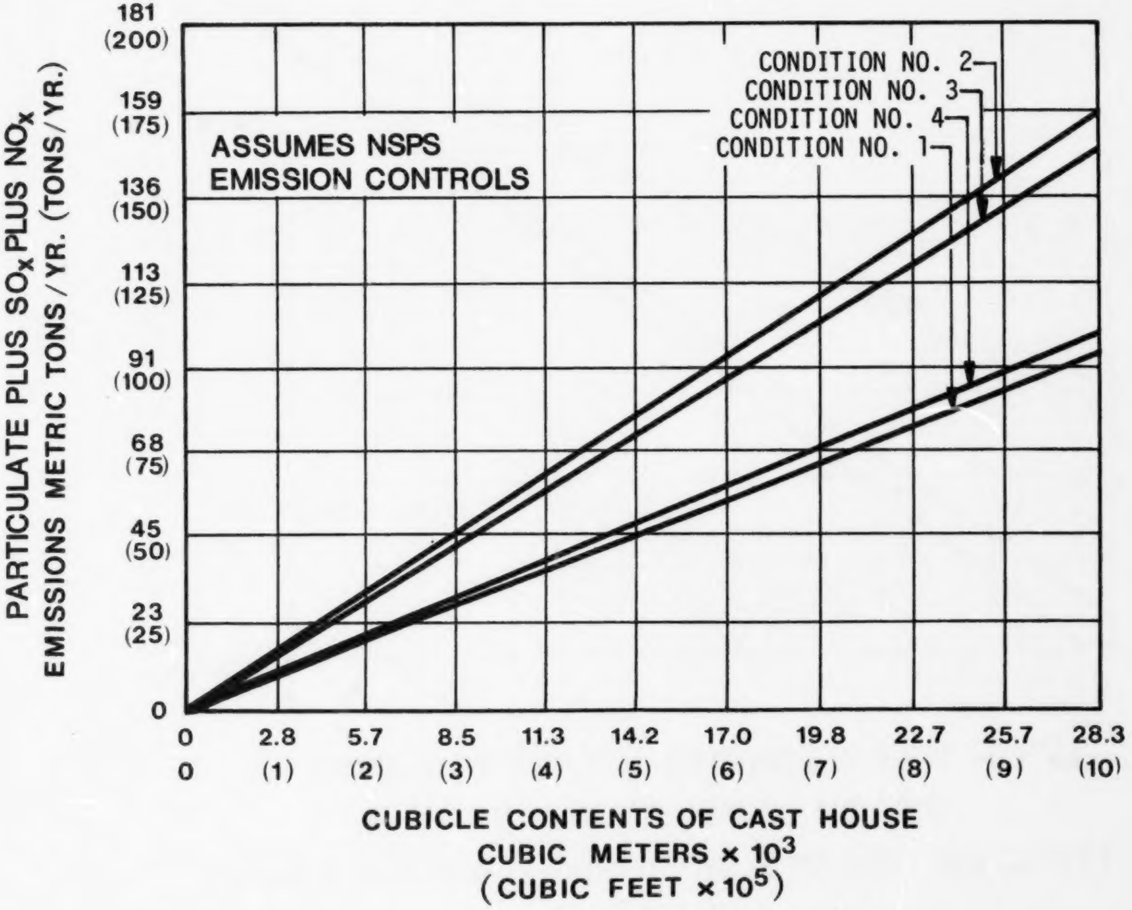


Figure 5-7

POWER HOUSE EMISSIONS CAUSED BY TOTAL EVACUATION OF CAST HOUSE

70 CAST HOUSE AIR CHANGES PER HOUR

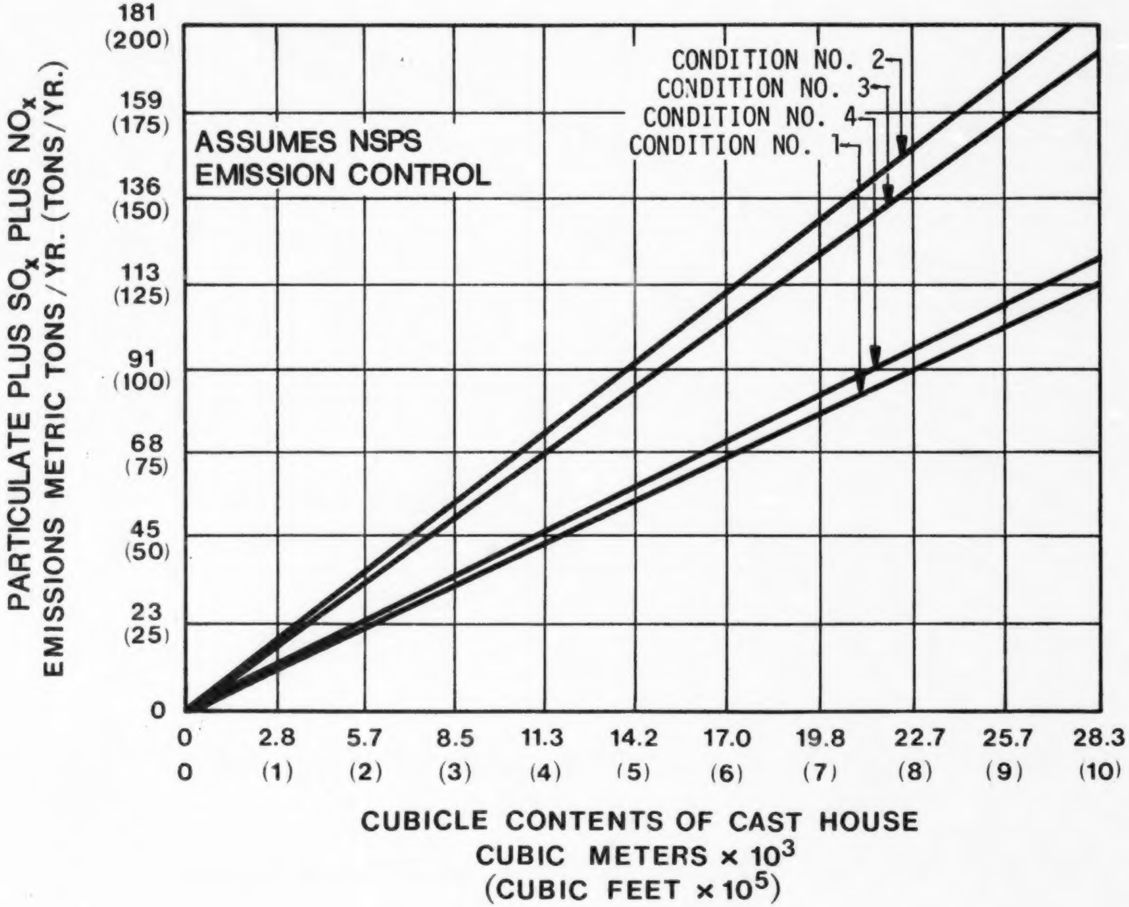
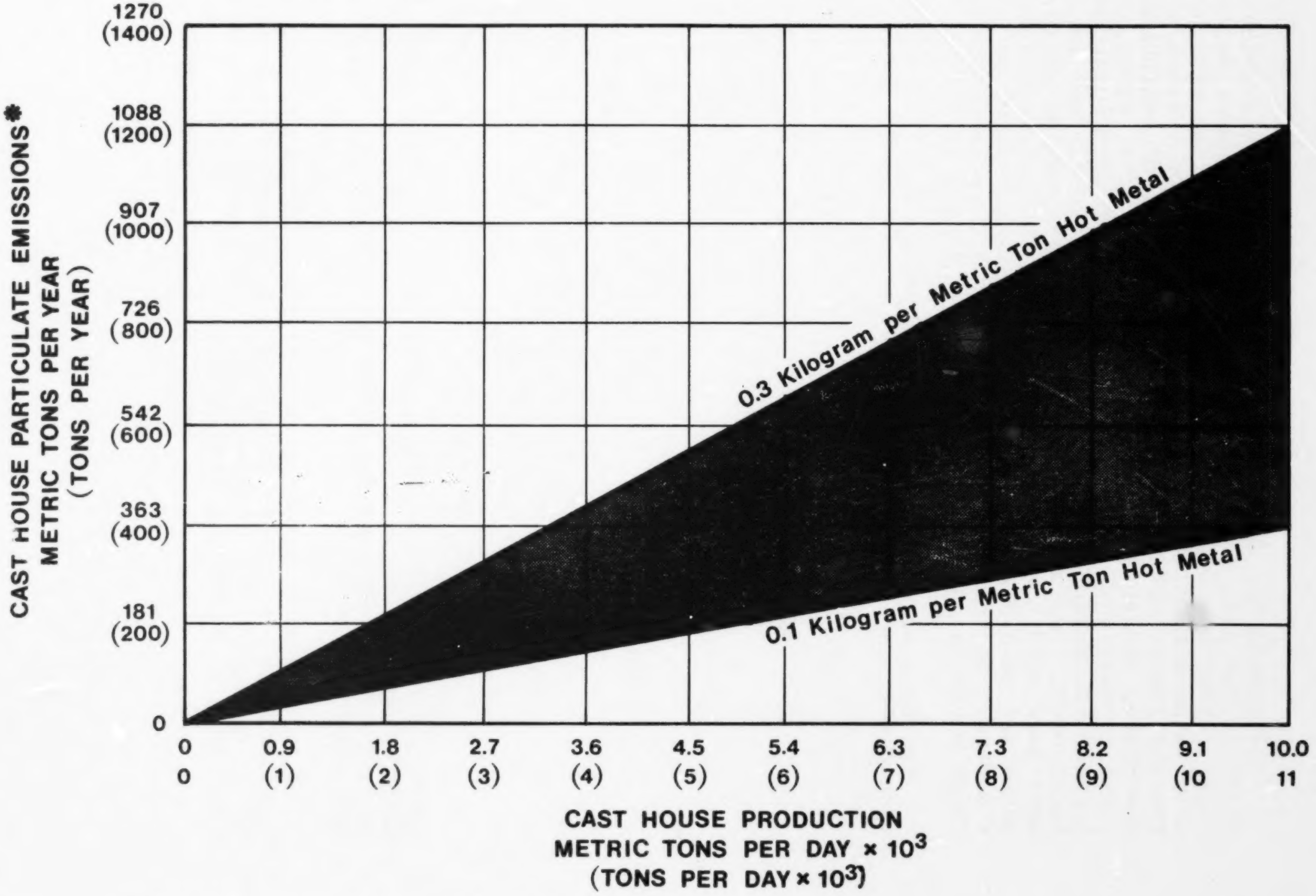


Figure 5-8

CAST HOUSE PARTICULATE EMISSIONS vs. PRODUCTION



*BASED UPON AN EMISSION FACTOR RANGE OF 0.1 TO 0.3 KILOGRAM PER METRIC TON HOT METAL (0.2 TO 0.6 LBS. PER TON)

"It should be noted however, that the areas in which steel plants exist are, for the most part, non-attainment areas. In these areas, new electrical generation facilities will not only have to meet NSPS, but must also have emission offsets so that the net result of new construction will be less pollution and, therefore, progress toward attainment. In clean areas, the new facility must meet prvention of significant deterioration (PSD) increments, which in some cases, would force control to levels below NSPS. Furthermore, the state implementation plans (SIP's) were developed to protect the health of the public and in many cases are more strict than NSPS, which is a technology based standard. In the instance of stricter SIP's, the stricter SIP rules would be the controlling regulations."(1)

The following are the fuels considered for each condition:

- Condition No. 1
    53.1% coal
    10.0% oil
    36.9% nuclear
- Condition No. 2
    100% coal
- Condition No. 3
    85% coal
    15% oil
- Condition No. 4
    51.6% coal
    18.4% oil
    30.0% nuclear

Condition No. 1 is the 1986 projection of Duquesne Light Company, Pittsburgh, Pa. while Condition No. 4 is a Bureau of Mines projection. Conditions No. 2 and No. 3 are B.E.E. hypothetical fuel usage estimates.

Sample calculations for each of the four power house fuel condition curves appears in Appendix B, pages B7 through B14. The calculations are presented for an evacuation rate of 189 cubic meters per second (400,000 CFM).

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(1) EPA Industrial Environmental Reserach Laboratory prepared comment.

GASEOUS EMISSIONS FROM CASTING

Since the sulfur content of steel is generally maintained below a maximum of 0.020% to retain desirable physical properties in the steel, the sulfur in the hot metal from the blast furnace is also held to a minimum.

The sulfur input to a blast furnace is from fuel, scrap or other additions from the burden. Most of these items depend a great deal on market conditions and cannot be readily controlled. The hot metal sulfur content is affected by operation of the furnace, and may be reduced by an external desulfurization process which is not only costly but would provide another area for fume emission.

Of the total sulfur leaving the furnace, approximately 95% is reported to be locked in the slag; the remainder is in hot metal and top gas. Because of limited contact with air and moisture, the sulfur in the slag runners does not readily oxidize to sulfur compounds such as SO_2 and H_2S. The odor threshold for odorous sulfur compounds is less than 1 ppm therefore a very small quantity of these gases may be detected as odorous. Sulfurous gases emissions to atmosphere will increase as casting time increases due to the increase in contact with air at runner surfaces. When the sulfur content of fuel is increased, the volume of slag per ton of hot metal is also increased. The basicity of the slag increases slightly as the cast proceeds.

A decrease in the CaO basicity ratio reflects an increase in sulfur content of hot metal. Hot metal production is increased and the coke rate is decreased.

The sulfur content of hot metal is decreased by increased slag volume and increased basicity ratio. This can only be done by increasing coke rate and consequently reducing the hot metal production. It would follow, then, that to increase blast furnace productivity and reduce coke rate, it would be necessary to decrease slag basicity; lower lime consumption decreases the slag volume and also the melting point of the slag. A decrease in iron content of the slag follows a decrease in the basicity of slag and the corresponding yield increase.

Desulfurization of the hot metal could be accomplished in the ladle or some other location external to the cast house.

A reported typical sulfur case, based on 500 Kg coke to make one tonne of hot metal (1000 lbs. coke per ton) with 1% sulfur in coal, shows 4.05 Kg/tonne (8.1 lb./ton) of sulfur in coke which divides to 3.85 Kg/tonne (7.7 lbs/ton) in molten slag and 0.2 Kg/tonne (0.4 lbs/ton) in hot metal which is 0.02% sulfur. This case produces 200 Kg of slag per metric ton of hot metal (400 lbs/ton). The slag carries about 95% of the sulfur. The rest is in the top gas and hot metal.

Other Gases

Traces of gaseous elements such as carbon monoxide (CO) normally occur in the tap hole emissions. Gaseous emissions from runner curing may come from the coke oven gas used to dry the clay and pitch linings and also from volatiles in clay and pitch during the drying process. These emissions occur for short durations during maintenance only. It is not unusual to have CO concentrations in the upper areas of the cast house structure, particularly around the blast furnace, which are sufficient to warrant the need for air packs by operating personnel. These CO concentrations come primarily from other sources in the furnace proper, including leakage through the furnace shell itself rather than from the tap hole during casting.

SECTION 6

STATE-OF-THE-ART FOR CAST HOUSE EMISSION CONTROL

U.S. TECHNOLOGY

As of the date of this report there are no operating fugitive air pollution control systems serving basic iron blast furnaces in the U.S.A. The cast house enclosing the ferromanganese blast furnace at Bethlehem Steel Corporation's Johnstown works has an emission control system utilizing the total evacuation concept. The quantity of emissions generated when casting a ferromanganese blast furnace were observed by B.E.E. to be substantially higher than from the basic iron blast furnaces observed. A ventilation rate of 189 cubic meters per second (400,000 CFM) is being used to totally evacuate the Bethlehem Steel Johnstown ferromanganese cast house and to filter the particulate matter through a cloth baghouse. Baffles were provided in the cast house to help localize the fumes for entrainment in the top hood. The baghouse collector extracts about 227 to 454 kilograms (500 to 1,000 lbs.) of dust per day from the exhaust volume. The system is considered by B.E.E. to be effective.

United States Steel Gary #13, with a furnace working volume of 2,832 cubic meters (100,000 cubic feet), has as its record a daily production a rate of 6,906 metric tons (7,614 tons) of hot metal and a current normal production of 5,624 metric tons (6,200 tons). The furnace has 3 tapholes of 48.26 millimeters (1.9 inches) diameter and casts 12 times per day.

When Gary #13 was blown in, consideration was given to containing the violent reaction at the tap hole by installing a domed hood, 1.82 meters (6 feet) wide by 0.91 meters (3 feet) high over the iron pool (which is about 12.19 meters (40 feet) long) to the skimmer. The tap hole on Gary #13 has an angle of 14°. The blast pressure is maintained at 1.735 E + 05 Pa(25 psig) from tapping to closing and the trough is not normally drained after each cast. Prior to the hood installation, coke messes had occurred several times a month and after installation, upset conditions persisted that precluded the further use of the hood. No further attempt has been made to install any other kinds of hooding or to experiment further with the trough cover.

The new large blast furnaces that are being constructed at Sparrows Point and East Chicago will have Japanese production and emission capture design modifications incorporated into their construction. Efforts are being made to collect all of the fumes generated through the use of an integrated iron making and fume capture system. The fume capture system will include close fitting trough and runner covers and hoods.

Bethlehem Steel Corporation has installed a partial drop-curtain type experimental hood at the tap hole area of Furnace E at Bethlehem, Pa. to determine the degree of effectiveness of fume control from this method of enclosure as used for primary capture of fugitive emissions. The retractable curtain was intended to capture fumes from the iron pool which extends from the tap hole to the skimmer while allowing a free area underneath for the mud gun and tap hole drill to function.

As reported by Bethlehem Steel Corp. and witnessed by B.E.E. on video-tapes, the experimental "E" Furnace system as initially installed was limited in its effectiveness, since the hood curtains were very susceptible to being drawn up into the exhaust take-off by the exhaust air flow. This occurred on two occasions and resulted in damage to the curtains. To avoid this problem Bethlehem implemented the following actions:

1. Restricted the air flow substantially by throttling the damper on the system fan to approximately 42.5 actual cubic meters per second (90,000 ACFM).

2. Raised the east curtain of the tri-curtain enclosure. The fourth side of the enclosure was a combination of the blast furnace and a steel plate..

Emission tests were conducted under these conditions, the results of which are reported in Section 5. The capture efficiency of the system was impaired, however, due to:

1. Reduced air flow

2. Short circuiting of air with the east curtain raised.

3. Air currents deflecting the unsecured curtains from a position directly above the iron trough.

Bethlehem then took "E" Blast Furnace out of service in order to remove the curtains and make modifications to upgrade system performance. A series of emission tests were conducted with the curtains removed and with the fan damper in the 100% open position. This condition resulted in an exhaust rate of approximately 141.5 actual cubic meters per second (300,000 ACFM). Again Bethlehem took "E" Blast Furnace out of service to install the modified curtain system which was designed to enable the hood to operate with the third (east) curtain in the down position and to permit increased exhaust flow rates. These modifications were:

1. Installation of weights (a length of pipe) on the lower edges of all three curtains.

2. Installation of guy wires on the west end of the north and south curtains.

3. Fabrication of temporary "supports" to secure the east curtain in the down position. Two sections of pipe were bent on one end; the bent end of one section was inserted through an eyelet on the east end of the north curtain and the bent end of the other section was inserted through an eyelet on the east end of the south curtain. The opposite ends of the pipes were secured to a railing on the cast house floor (south pipe) and to a bar attached to a building column on the north side of the cast house.

With the curtain system secured as described above, the fan exhaust damper was opened substantially wider than the setting used in the earlier tests. Based upon Bethlehem's visual observations the exhaust volume was increased to the maximum flow that the fabric curtains could tolerate without collapsing inward due to negative pressure within the hood. As observed by B.E.E. in the video-tapes the fume capture efficiency of this system was markedly superior to the earlier attempts. The system as used, however, is not considered feasible by Bethlehem Steel Corp. or B.E.E. for a permanent installation because of the limited durability of the curtains, the difficulties of securing the curtains to obtain the necessary stability and the safety hazards associated with suspending weights above the trough.

Conceptually, this zoned capture system at Bethlehem shows promise because it can be relatively effective in capturing a high percentage of the fumes. However, the operating and maintenance problems, along with construction details and durability of the entire system, will have to be satisfactorily worked out to achieve an operable installation.

In summation, the state-of-the-art of controlling cast house emissions in the United States has not been developed extensively and minimal research and development efforts have been reported.

JAPANESE TECHNOLOGY

The Japanese first implemented cast house emission control in the mid-1960's on new blast furnaces and have improved the technology during the intervening years. They have retrofitted cast houses with capture-control systems, but these are generally associated with complete blast furnace and cast house rebuild projects. According to Nippon Kokan K.K. (NKK), 100% of all

Japanese blast furnace cast houses have some degree of emission control.

The Japanese technology presented herein is a review of meetings with Nippon Steel Corporation and Nippon Kokan K.K. (NKK) at their main offices in Tokyo and plant visits to the Oita, Kamaishi and Fukuyama works in February 1976. Although these meetings and visits do not allow a detailed assessment of the technology of cast house emission control in Japan, they do allow an assessment to be made of the state-of-the-art for controlling cast house emissions in Japan.

In general, the Japanese do show that blast furnace cast house emission control can be effectively implemented. Several factors, including the following, have aided in their success:

1. Government support of steel industry
2. An advanced blast furnace technology
3. Excellent burden materials
4. Few upset conditions
5. Japanese cast houses are all large and relatively new installations
6. Multiple tap hole furnaces which allow flexibility in operating practice.

In addition to the above, two other factors have assisted in the development and application of cast house emission control technology:

1. A very strong national concern for maintaining environmental quality
2. A competitiveness between steel companies to install environmental control measures

The Japanese approach considers emission capture as a part of blast furnace cast house design.

Japanese workers usually spend a lifetime working for a single employer. This tenure and dependence plus other historic cultural patterns of behavior have resulted in a high standard of work performance by all levels of Japanese workers. This has considerably reduced the malfunction potential. Operating malfunctions are the single most important reason that doubt exists as to the successful application of Japanese technology to other situations, such as U.S. operations.

There are three major concerns about air pollution in Japan: SO_x, NO_x, and dust. No central government laws govern the emissions from cast houses. Local government laws and restrictions vary from location to location, but generally these rules or laws limit visible emissions to zero and limit total steel works emissions to a certain amount of kilograms per hour.

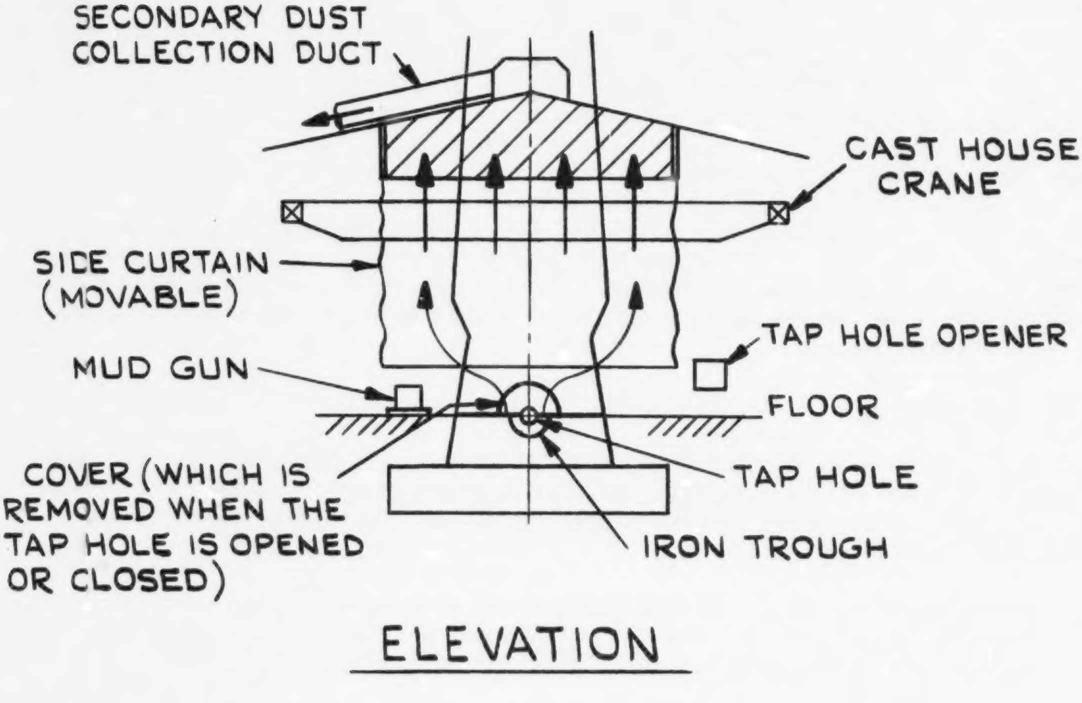
All cast house dust collection systems observed and discussed have certain similarities. In addition to local hoods (identified as primary systems) installed close to dust sources, considerations were given to secondary dust collection systems in which dust is removed from the cast house at its roof or with special retractable hoods installed using the upper part of the cast house building as a major component of the hoods. Although tap holes and iron troughs are the major dust sources in the cast house, the effectiveness of local hoods is reduced because of the need to remove them during the operation of tap hole drills and mud guns. As a result, a significant fraction of the total emissions escape capture by the primary system. To cope with this problem, the Japanese have successfully developed secondary dust collection equipment which can effectively capture the emissions escaping the primary system. Figure No. 6-1 is a schematic representation of a concept as developed by Nippon Steel Corporation. Through the years, various attempts have been made by the Japanese to improve local hoods so that optimum dust collection can be achieved without sacrificing working efficiency in the cast house.

AISI Comment

The following comment on the differences between Japanese and United States blast furnace operating practice has been provided by the AISI ad hoc working group on blast furnace cast house emission control:

> "We believe that the distinctions between Japanese and United States practice is discussed inadequately in the report. We offer the following paragraphs as an amplification:
>
> Presently, there is only one operating blast furnace in the United States with emission control. This blast furnace is a ferromanganese furnace which has a total cast house evacuation system, an approach that had to be made due to the unusual emissions from this type of hot metal. These emissions are quite different from those from basic hot metal.
>
> All blast furnaces in the United States, except for 10, are equipped with one tap hole and one iron runner system from that tap hole. All blast furnaces in Japan have more than one tap hole and more than one iron runner system from the tap holes. Further, all of the operating blast furnaces in

Figure 6-1
REPRESENTATION OF NIPPON STEEL CORPORATION'S SECONDARY DUST COLLECTION SYSTEM


SECONDARY DUST COLLECTION DUCT
CAST HOUSE CRANE
SIDE CURTAIN (MOVABLE)
TAP HOLE OPENER
MUD GUN
FLOOR
COVER (WHICH IS REMOVED WHEN THE TAP HOLE IS OPENED OR CLOSED)
TAP HOLE
IRON TROUGH
ELEVATION

Japan, by virtue of either being greenfield plants or having been completely rebuilt since 1960, have modern cast houses which are provided with ample space for storage of cast house material and movement of support equipment. They were designed to handle the hot metal tonnages from the blast furnace at present rated capacity. In the United States, on the other hand, the great majority of the present operating furnaces were built before 1960 and utilize original cast houses that were designed to handle less than 50% of the present-day capacity. These older cast houses tax the operations to be able to maintain present levels of productivity while properly maintaining trough and iron runners. Utilization of present Japanese technology to capture fugitive emissions within the cast house would impose further limitations on proper maintenance of trough and iron runners at present operating levels.

Very few blast furnaces in the United States are provided with stockhouse screening and ore and coal bedding systems that minimize variations in hot metal chemistry and temperature on a cast-to-cast basis. All Japanese furnaces are provided with sizing and bedding systems for all materials utilized and all burden materials are screened to remove unwanted fines before they are charged to the furnace. With the higher degree of control of the essential elements in the hot metal and its temperature, the Japanese have practically eliminated "scrappy," off-iron that necessitates increased iron runner maintenance. In the United States, the wider variation of hot metal chemistry and temperature makes iron runner maintenance more severe than in Japan. The use of runner hooding would add to this disadvantage. It should be noted that the iron runner system in the modern Japanese furnaces, and they are all modern, are removable and require one to three relines per month whereas the American blast furnace iron runner system requires daily maintenance."

Nippon Kokan K.K. (NKK)

NKK provided survey information on all Japanese blast furnace operations. This information is presented in Table 6-1.

NKK's Technical Approach and Philosophy-

NKK's philosophy of cast house emission control is to look first at primary evacuation through the use of hoods and covers and then at secondary or total building evacuation.

Primary Evacuation System-- NKK employs two styles of local tap hole hooding. Style No. 1 is with the hood fixed over the tap hole and trough in the immediate vicinity of the tap hole. Style No. 2 has two hoods, one on either side of the trough at

TABLE 6-1

SURVEY INFORMATION
JAPANESE BLAST FURNACE
EMISSION CONTROL

1. Primary (local hoods)

Percentage of all Japanese plants with capture hoods:

- 100% at iron spouts
- 80% at tapping holes
- 66% at runners
- 4% at slag holes. The reason for this low percentage is because there are few Japanese plants employing slag holes.

Control Systems

- 83% use baghouses
- 8% use electrostatic precipitators
- 6% use scrubbers
- 4% use combination of above

Evacuation flow rates;

- Average 133 actual cubic meters per second (282,500 ACFM)

2. Secondary (total house) Evacuation

Control Systems

- 95% use baghouses
- 5% use electrostatic precipitators

Evacuation Flow Rates

- Average 167 actual cubic meters per second (353,000 ACFM).

3. Total primary and secondary: 45 to 80 air changes per hour (based on cast house internal volume).

the tap hole. In addition to hoods at the blast furnace tap holes, hoods are also installed at the skimmers and iron spouts. It is from these three locations that evacuation is applied. Between the hoods, trough and runner covers are installed to create a sort of a flue or duct over the exposed hot metal which prevents emissions from escaping the influence of the primary system hoods. Style No. 2 hoods are moveable and are preferred to the fixed type style No. 1 hood because the hoods can be installed closer to the iron and consequently are more effective. Occasionally, however, hoods on both sides of the trough cannot be installed because of insufficient clearance.

Through February 1976, none of the primary hoods has had to be replaced, the oldest being approximately five years old. NKK experienced no problems with hoods being destroyed during developmental stages of cast house emission control. The primary evacuation hoods and covers must be periodically relined.

It is the opinion of NKK officials that most of the dust generated in the blast furnace is captured by primary evacuation. Secondary evacuation is implemented because of local environmental regulations. Secondary evacuation prevents visible fugitive emissions from escaping the building through the roof monitors.

NKK has never attempted to determine the percentage of emissions which are generated in the tap hole and iron trough vicinity. A very rough estimate of 80% was mentioned.

Secondary evacuation System--The total evacuation system employed by NKK does not use curtains or shields to try to isolate any one area for total evacuation. The system uses a roof monitor takeoff. The roof monitor has an emergency by-pass to the atmosphere. If an upset condition occurs and the evacuation system cannot be used, a duct damper will open, exhausting the cast house by natural ventilation. NKK does, however, install the total evacuation take-off duct at a location in the roof near the blast furnace.

NKK does not have furnaces with a single taphole. Therefore, they could not relate to the application of a cast house emission control system employing the primary capture concept to single taphole furnaces.

NKK's officials believe that the implementation of blast furnace cast house emission control has been cause for some reduction in operational efficiency, but they were unable to indicate the extent.

NKK has only applied baghouses on cast house emissions. They have not tried any other types of control. The Keihin Works which is scheduled for shutdown in 1978 is the lone NKK operation which has only primary or local evacuation. The size of the blast furnace is 1,830 cubic meters (64,600 cu. ft.), inner volume. The evacuation rate from the tapping hole area is 50 normal cubic meters per second (106,000 ACFM). The evacuation of the iron spout area is 38 normal cubic meters per second (81,000 ACFM). No modifications were necessary to the cast house to implement this system.

NKK is presently building an integrated steel mill on Ogishima Island in Tokyo Bay. This facility is located in a highly populated area and will have a cast house evacuation flow rate of 250 actual cubic meters per second (530,000 ACFM) and a 250 actual cubic meters per second (530,000 ACFM) local evacuation.

Fukuyama Works-

The Fukuyama Works of NKK located on reclaimed land in the inland sea of Hiroshima Prefecture is the largest of their two integrated steel mills. This works was visited on February 23, 1976. A second mill - the Keihin Steel Works - is located in the Tokyo area. Steel making at Keihin will be discontinued after operations at a new mill under construction on Ogishima Island are completed. Table 6-2 presents technical and statistical information pertaining to blast furnace No. 1 at the Fukuyama Works.

During the cast house visit, casting from only one tap hole was witnessed. The cast house contained a noticeable amount of fumes, especially near the conclusion of the cast. The fumes lingered in the secondary system zone but eventually were evacuated from the cast house. Discussions with NKK personnel and field observations yielded the following salient items:

1. Some primary system hoods and ducts are refractory lined, but to what extent could not be determined.

2. NKK has experienced some problems with burning holes in the primary system baghouse fabric. Consequently, drop-out chambers have been installed on the inlets to the primary system baghouses.

3. Gas temperatures in primary baghouses normally run between 60°C (140°F) and 80°C (170°F).

4. NKK normally uses negative pressure baghouses with stacks. They have previously tried positive pressure systems, but because of fan problems they switched to negative systems.

5. Primary systems do not have dilution air capabilities.

TABLE NO. 6-2

FUKUYAMA WORKS - BLAST FURNACE AND CAST HOUSE TECHNICAL AND STATISTICAL INFORMATION

1. BLAST FURNACE NO. 1

2,323 m^3 (82,000 ft^3) blast furnace inner volume, blown-in 1966 with a cast house emission control system - the first one in Japan. Needed improvement, more capacity and increased efficiency. System modified in 1969 during a reline.

Primary System: 1 baghouse - 75 AM^3/Sec (159,000 ACFM)
Secondary System: 1 baghouse - 83 AM^3/Sec (176,000 ACFM)

System not effective because of insufficient ventilation rates. Subsequent system rates on other cast houses have been increased.

2. BLAST FURNACE NO. 2

2,828m^3 (99,850 ft^3)blast furnace inner volume.

Primary System: 1 baghouse - 75 AM^3/Sec (159,000 ACFM)
Secondary System: Under Construction: 2 baghouses - 125 AM^3/Sec (159,000 ACFM) per baghouse.

Air-to-cloth ratio is 0.017 meters/sec (3.4 ft./min) on secondary system baghouses.

3. BLAST FURNACE NO. 3

3,016m^3 (106,500 ft^3) blast furance inner volume.

Primary System: 2 baghouses - 125 AM^3/Sec (265,000 ACFM) per baghouse
Secondary System: 2 baghouses - 83 AM^3/Sec (176,000 ACFM) per baghouse

Air-to-cloth ratio is 0.017 meters/sec (3.4 ft./min)

Initially installed primary system only, secondary system was added latter.

4. BLAST FURNACE NO. 4

4,197m^3(148,200 ft^3)blast furnace inner volume.

Primary System: 1 baghouse - 83 AM^3/Sec (176,500 ACFM)
Secondary under construction: 2 baghouses - 125 AM^3/Sec (265,000 ACFM) per baghouse.

Air-to-cloth ratio: 0.017 meters/sec (3.4 ft./min) on secondary system baghouses.

5. BLAST FURNACE NO. 5

4,617m^3 (163,000 ft^3) blast furnace inner volume. See Figures No. 6-2 and 6-3 for sketches of the cast house emission capture system.

Primary System: 2 baghouses - 125 AM^3/Sec (265,000 ACFM) per baghouse
Secondary System: 2 baghouses - 83 AM^3/Sec (76,500 ACFM) per baghouse

Air-to-cloth ratio is 0.017 meters/sec. (3.4 ft./min.) all baghouses.

Primary System Flow Rates - Cast from one tap hole

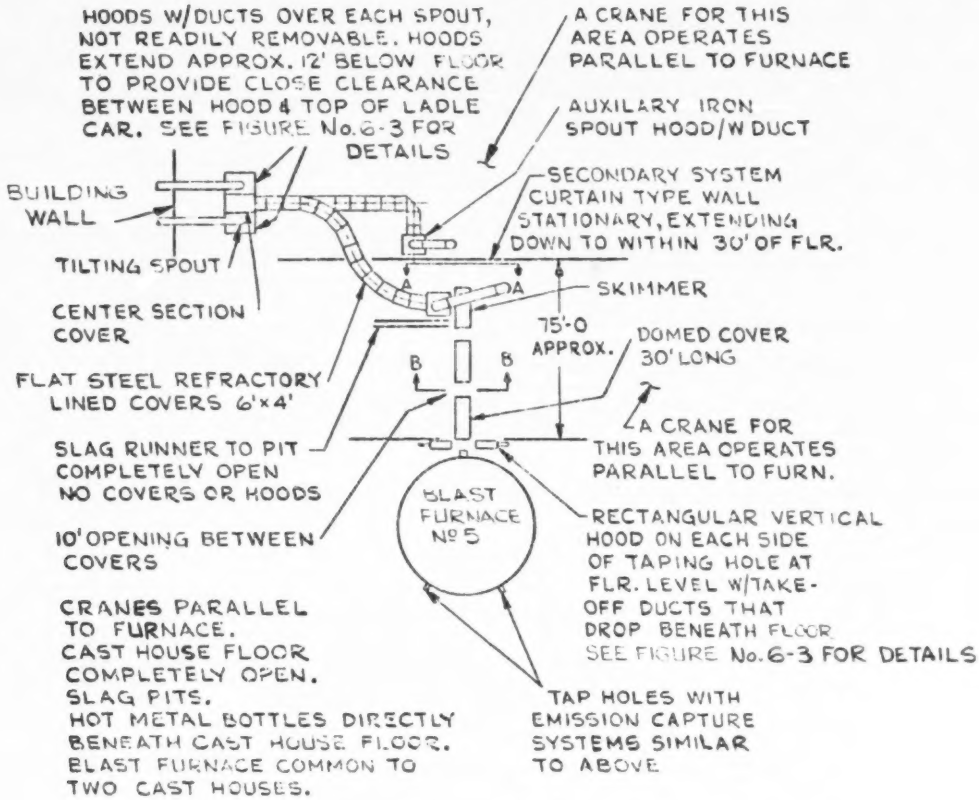
Tapping hole:	33 AM^3/Sec (70,500 ACFM)	
Spout:	42 AM^3/Sec (88,250 ACFM)	each os 2 ducts.
Skimmer:	17 AM^3/Sec (35,500 ACFM)	
Iron Runner:	33 AM^3/Sec (70,500 ACFM)	
Spare:	83 AM^3/Sec (176,500 ACFM)	

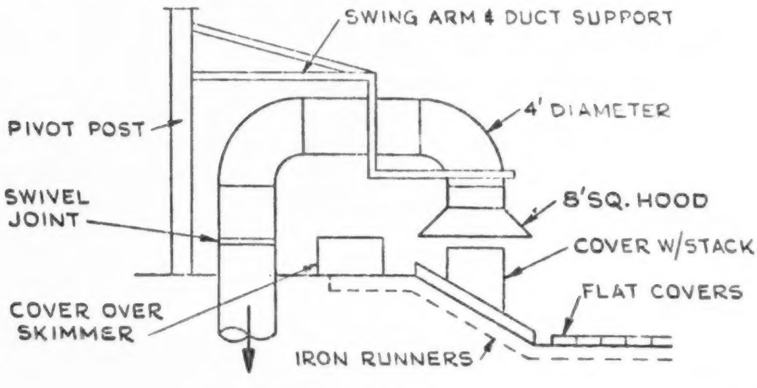
Primary System Flow Rates - Cast from two tap holes simultaneously.

Tapping hole:	25 AM^3/Sec (53,000 ACFM)	each of 2 hoods
Spout:	25 AM^3/Sec (53,000 ACFM)	each of 4 ducts
Skimmer:	17 AM^3/Sec (35,500 ACFM)	each of 2 hoods
Iron Runner:	29 AM^3/Sec (62,000 ACFM)	each of 2 hoods

Figure 6-2

NIPPON KOKAN K.K. FUKUYAMA WORKS
BLAST FURNACE No. 5 EMISSION CAPTURE SYSTEM


HOODS W/DUCTS OVER EACH SPOUT, NOT READILY REMOVABLE. HOODS EXTEND APPROX. 12' BELOW FLOOR TO PROVIDE CLOSE CLEARANCE BETWEEN HOOD & TOP OF LADLE CAR. SEE FIGURE No. 6-3 FOR DETAILS
A CRANE FOR THIS AREA OPERATES PARALLEL TO FURNACE
AUXILARY IRON SPOUT HOOD/W DUCT
BUILDING WALL
SECONDARY SYSTEM CURTAIN TYPE WALL STATIONARY, EXTENDING DOWN TO WITHIN 30' OF FLR.
TILTING SPOUT
A
A
SKIMMER
CENTER SECTION COVER
75'-0 APPROX.
DOMED COVER 30' LONG
FLAT STEEL REFRACTORY LINED COVERS 6'×4'
B
B
A CRANE FOR THIS AREA OPERATES PARALLEL TO FURN.
SLAG RUNNER TO PIT COMPLETELY OPEN NO COVERS OR HOODS
BLAST FURNACE Nº 5
RECTANGULAR VERTICAL HOOD ON EACH SIDE OF TAPING HOLE AT FLR. LEVEL W/TAKE-OFF DUCTS THAT DROP BENEATH FLOOR SEE FIGURE No. 6-3 FOR DETAILS
10' OPENING BETWEEN COVERS
CRANES PARALLEL TO FURNACE.
CAST HOUSE FLOOR COMPLETELY OPEN.
SLAG PITS.
HOT METAL BOTTLES DIRECTLY BENEATH CAST HOUSE FLOOR.
BLAST FURNACE COMMON TO TWO CAST HOUSES.
TAP HOLES WITH EMISSION CAPTURE SYSTEMS SIMILAR TO ABOVE

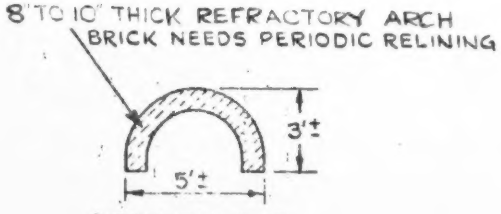

SWING ARM & DUCT SUPPORT
PIVOT POST
4' DIAMETER
SWIVEL JOINT
8'SQ. HOOD
COVER W/STACK
FLAT COVERS
COVER OVER SKIMMER
IRON RUNNERS

SECTION A-A

CONVERSION FACTORS

1 ft. = .305 m

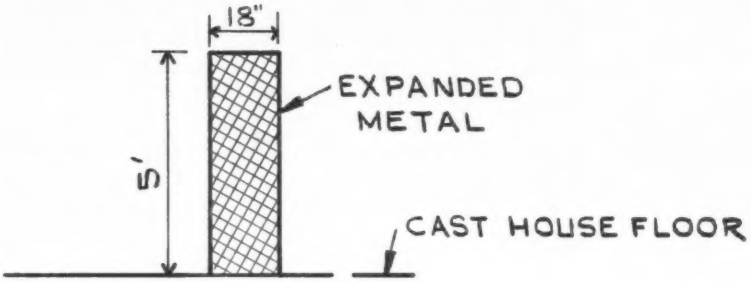
1 m = 25.4 mm


8" TO 10" THICK REFRACTORY ARCH BRICK NEEDS PERIODIC RELINING
3'±
5'±

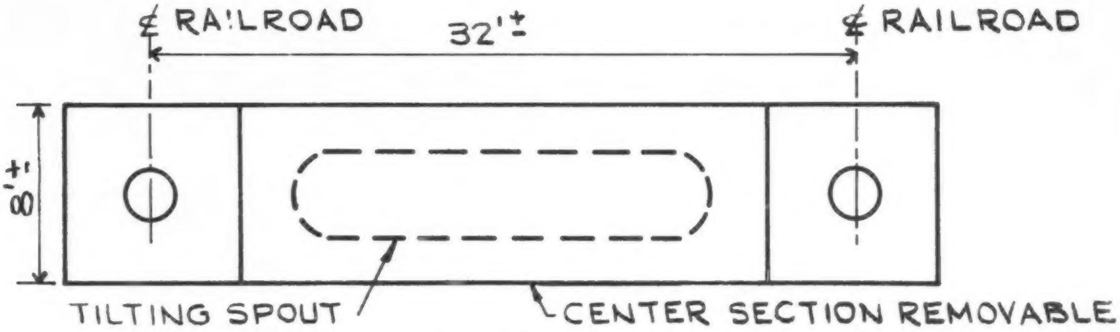
SECTION B-B

Figure 6-3

NIPPON KOKAN K.K. FUKUYAMA WORKS
BLAST FURNACE NO. 5 EMISSION CAPTURE SYSTEM
TAP HOLE AND IRON SPOUT HOOD DETAILS


18"
EXPANDED METAL
5'
CAST HOUSE FLOOR

FRONT ELEVATION
TAP HOLE HOOD

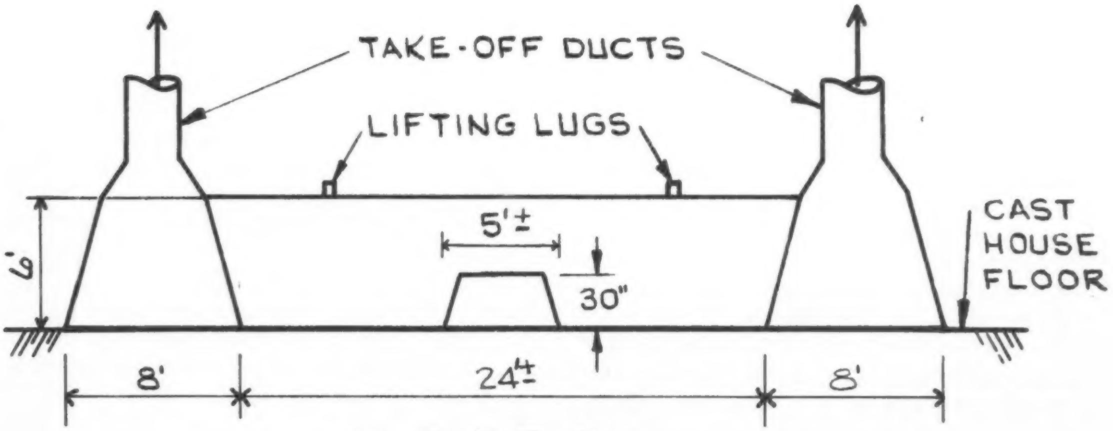

℄ RAILROAD
32'±
℄ RAILROAD
8'±
TILTING SPOUT
CENTER SECTION REMOVABLE

PLAN
IRON SPOUT HOOD

CONVERSION FACTORS

1 ft. = .305 m

1 m = 25.4 mm


TAKE-OFF DUCTS
LIFTING LUGS
5'±
30"
6'
CAST HOUSE FLOOR
8'
24'±
8'

ELEVATION
IRON SPOUT HOOD

6. No data were available on quantity of "dust collected" by baghouses.

7. Baghouse dust was not being sent to a new pelletizing plant because of start-up problems. Within a year of our visit dust will be pelletized then returned to the blast furnace. Dust is now used for fill material.

8. Blast furnace No. 4 primary system had no hood at the tapping hole. The theory is that tapping and plugging fumes will be captured by the secondary system.

9. B.F. No. 5 top gas pressure: 1.471 E + 05 Pa to 9.806 E + 04 Pa (21.33 psig to 14.22 psig)

10. It could not be determined to what extent the soaking bar technique is used at Fukuyama.

11. NKK does not design to a specific parameter of cast house volume air changes per hour. They did indicate, however, that air change rates of anywhere from 45 to 80 per hour can be found throughout Japan.

12. The following air sampling data was obtained by NKK in 1973 at the system baghouses on blast furnace No. 5 cast house:
Primary System

Baghouse inlet	0.538 grams/NM^3
Baghouse outlet	0.02 grams/NM^3

Secondary System

Baghouse inlet	0.078 grams/NM^3
Baghouse outlet	0.011 grams/NM^3

Improvements, in the form of increased primary and secondary evacuation rates, have been made to the emission capture systems since the above data were collected. Consequently, the present evacuation rates of 250 Am^3/Sec (530,000 ACFM) for the primary system and 163 Am^3/Sec (353,000 ACFM) for the secondary system cannot be used to determine an emission factor. NKK was not able to provide information on evacuation rates employed during sampling. The data does show that for this installation the primary system baghouse inlet contains particulate matter at a concentration which is almost seven (7) times greater then the concentration at the secondary system baghouse inlet.

Nippon Steel Corporation

Nippon Steel's first attempts at blast furnace cast house emission control took place in about 1968 and were associated with a new furnace. The first attempt did not have a curtain type secondary system. It had hoods over runners and troughs and spouts. Secondary system improvements were made with the implementation of a curtain.

Improvements in both operating tactics and physical features of covers and hoods has taken place through the years to increase performance life and decrease maintenance.

Nippon Steel Corporation has twenty-six blast furnaces; fourteen are equipped with secondary dust collection equipment; the remaining furnaces will be equipped with secondary dust collection equipment as their repair schedules occur. Of the two Nippon Steel Corp. blast furnaces visited under this contract, Oita No. 1 has complete equipment which can be considered typical of new blast furnaces, while Kamaishi No. 1 has equipment typical of relined and improved blast furnaces. Nippon Steel Corp. experienced great difficulty in installing the secondary hoods and monitors in Kamaishi No. 1 because belt conveyors and other existing equipment hampered the remodeling of the cast house building.

Nippon Steel Corporation's Technical Approach-

Nippon Steel approaches blast furnace cast house emission control through two means: (1) primary dust collection, which is defined as dust collection at tapholes and cinder notches, and (2) hoods over iron troughs, spouts, etc. Nippon Steel feels that primary dust collection is not always completely effective in capturing emissions during tapping and plugging because dusting (emissions) is most severe at this time and a portion of the primary capture system must be removed for drill and mud gun accessibility.

In order to improve upon the dust capture system, a secondary system is normally employed. The secondary system involves total cast house evacuation. This approach is to try to localize total evacuation to the areas around the taphole. A movable curtain is dropped into the working area of the blast furnace during tapping and plugging and lifted above the crane during other times to enable the crane to be used effectively. Nippon Steel feels this approach improves the effectiveness of the secondary system because the total effort of evacuation is concentrated in those areas of higher dust generation.

Figure 6-4 is an illustration from Nippon Steel Corporation's publication entitled "Blast Furnaces" and presents its dust and fume collecting system. Nippon Steel feels that the details of

Figure 6-4

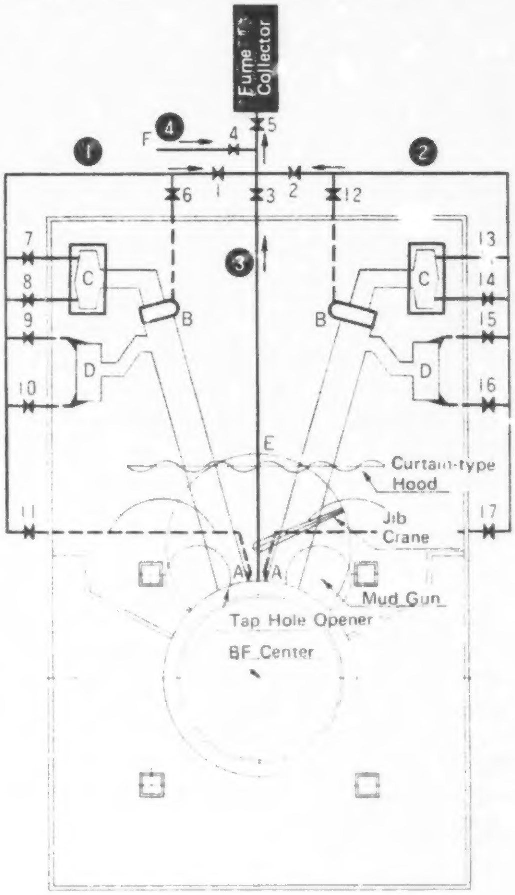
NIPPON STEEL CORPORATION'S CAST HOUSE EMISSION CONTROL SYSTEM

1. The flow sheet on the right is one for a two-tapping-hole cast house.
2. Code
   - A Tapping hole
   - B Skimmer
   - C Tilting runner for hot metal
   - D Tilting runner for slag
   - E Curtain-type collecting hood or monitored collector
   - F Hood for furnace-top conveyor

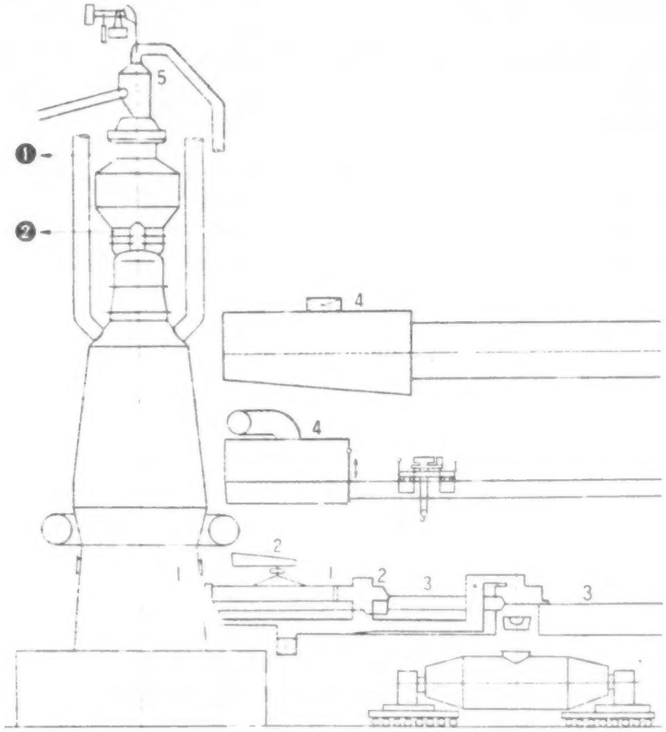
Dumpers
- 1–4 Dumpers for Main Duct
- 5 Dumper at collector inlet
- 6–17 Flow control dumpers for branch pipes
- Note: Dumpers 7 and 8, 9 and 10, 13 and 14, or 15 and 16 may be installed together at the same location.

3. Other Information
   - (1) Flow sheet
     - ———— Piping installed on ground
     - - - - - - - - - Piping buried underneath cast house or under concrete slabs
   - (2) Dumper operation
     Collector systems (1) to (4) are operated by controlling Main Dumpers 1 to 4.

Flow Sheet of Cast House Collecting System



Dust and Fume Collecting Systems at Furnace Top and Cast House



1. Dust and fume collection at Tapping Holes
2. Collection at Skimmer
3. Collection at the Tips of Iron and Slag Runners
4. Cast-house secondary collection (with curtain-type hood)
4'. Cast-house secondary collection (by monitoring)
   Note: Either 4 or 4' is used for the cast house.
5. Hood for furnace-top conveyor

❶& ❷ Furnace-top collectors (independent of collectors 1 to 5)

(1) Cover for Main Iron Trough
(2) Jib crane for Main Iron Trough Cover
(3) Runner Cover

both it's primary and secondary collection systems are proprietary.

The secondary system normally employs three curtains that cover three sides of the blast furnace; the fourth side is the blast furnace. The top of the hood would be the roof of the cast house. Curtains are dropped down two times during a casting cycle, during tapping and plugging. At all other times the curtain is raised to allow for normal activity. The area enclosed by the curtain is important. If it is too small, capturing dust will be ineffective. If it is too large, the system fan will need to be larger than is necessary to be effective.

During tapping and plugging the secondary system is operated to its fullest extent, while the primary system evacuation rate is reduced. At all other times the secondary system is closed, while the primary system is operated to its fullest extent, with the flow from the various pick-up points in the primary system varying between one another.

The hoods over the runners, spouts and troughs are fixed. Ducts from the hoods drop beneath the floor so they are out of the way of the crane. Between these hoods the runners, troughs and spouts have removable covers which are placed to enclose the hot metal, forming a flue or duct between the covers and the hoods.

Nippon Steel uses both top and side hoods. The top hood is more effective, while the side hood is used primarily because of accessibility. That is, the top hood cannot be effectively used because of lack of space.

Not all runner covers are refractory lined. Covers are lined only in the areas of most turbulence where iron can come in contact with the covers. Generally this is in the area of the tapping hole and the iron trough.

Immediately after the installation of a control system there is normally some problem with the crane operator and his awareness of the presence of hoods, covers and ducts. Through time, his increased awareness of the system decreases equipment damage.

Nippon Steel feels that an important design parameter for the primary control system is the curvature of the covers for the troughs and runners. The curvature has to be great enough to allow for the proper flow of air for cooling and proper evacuation at the hood. The normal temperatures of the air or gas in the primary system hoods and ducts were not indicated.

Nippon Steel feels that the amount of dust generated by a blast furnace cast house varies with operating conditions. It is not in a position, however, to discuss these operating conditions and variables in detail. There are no data available on the amount of dust generated or captured at any of it's works. Nippon Steel's rough estimate of the percentage of dust generated in the vicinity of the tapping hole is in the 30 to 40% range. Blast furnace flushing is not a normal activity at Nippon's mills.

Nippon has tried control devices other than baghouses. Presently, baghouses are the only devices it recommends and the only devices it is pursuing. "The efficiency of the fabric filter is excellent, and a fabric filter doesn't have the wastewater problem associated with a wet scrubber."

Nippon Steel feels that the key element in the successful implementation of a blast furnace cast house emission control system is the awareness of the operator and effective operations. This includes the operators timing in switching from the primary to the secondary dust collecting system, his awareness of maintaining and checking covers, etc. There basically is no difference in a blast furnace emission control system for a new or old cast house system except possibly for space limitations and certain physical restraints on older type operations.

Nippon Steel does not have any single tap hole furnaces. It feels that the operation of a single tap hole furnace would be too small to justify economically. Additionally, it feels that with a single tap hole furnace, the space requirements for a curtain probably could not be met.

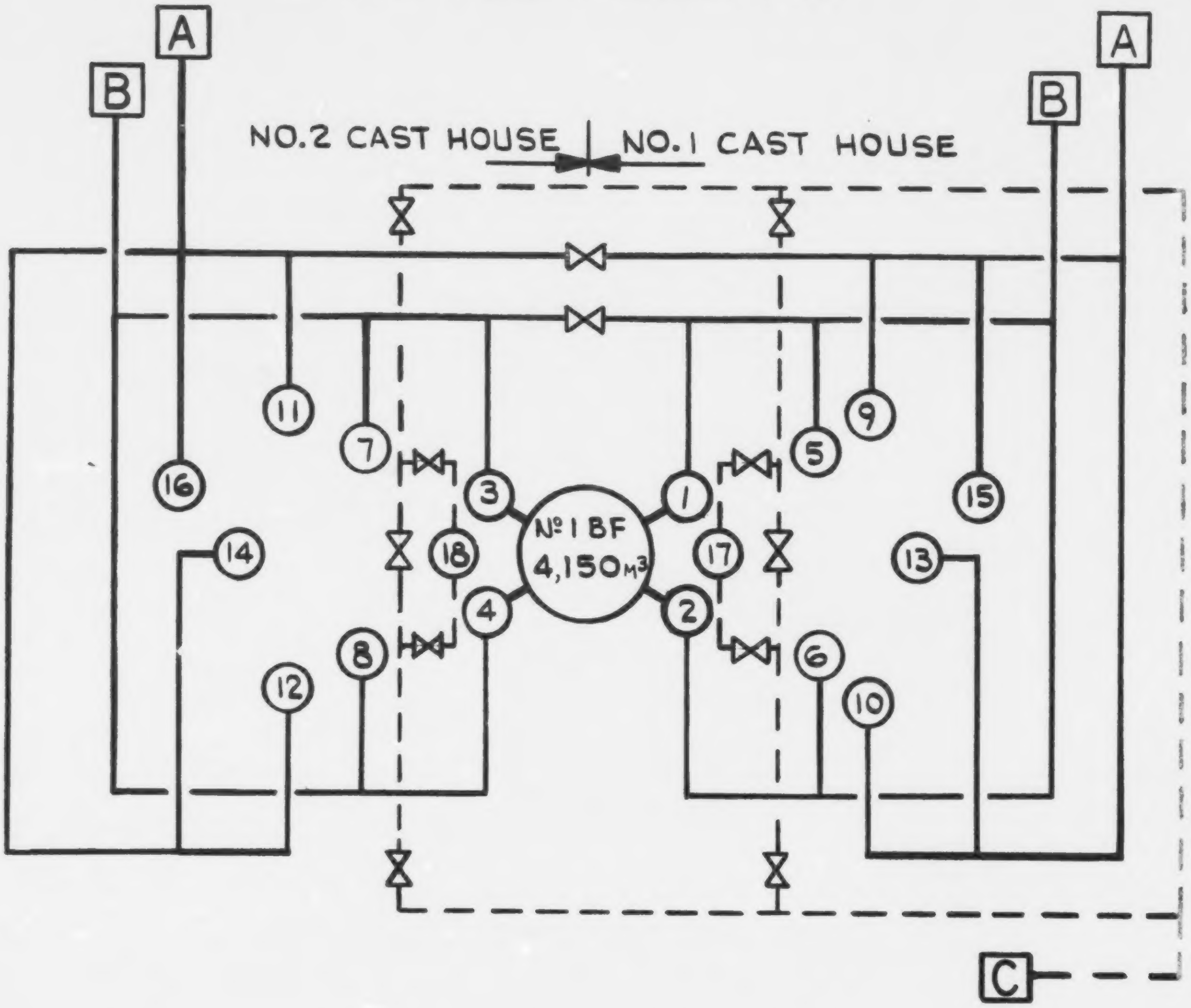
Oita Works-

The Oita Works, which was visited on February 18, 1976, is a new integrated mill located on reclaimed land in a natural bay on the southern island of Kyushu. The works was inaugurated in June, 1971 with B.F. #1 blown-in in April, 1972. Construction was recently completed on B.F. #2. Both B.F. #1 and #2 have primary and secondary cast house emission control systems originally designed with the facility (See Figures 6-5, 6-6 and 6-7 for a schematic diagram and field sketches of the Oita B.F. #1 cast house emission control system). The emission control system for blast furnace cast house #2 was not inspected.

The mill generally was exceptionally clean, though how much of this was due to reduced capacity was unknown. B.F. #1 cast house was also exceptionally clean with no debris, sand, etc. littering the floor. In fact, the floor had recently been washed down. Table 6-3 presents technical and statistical information pertaining to blast furnace No. 1 and its cast house at Oita.

Figure 6-5

SCHEMATIC DIAGRAM OF CAST HOUSE DUST COLLECTION AT OITA No.1 B.F. NIPPON STEEL CORPORATION

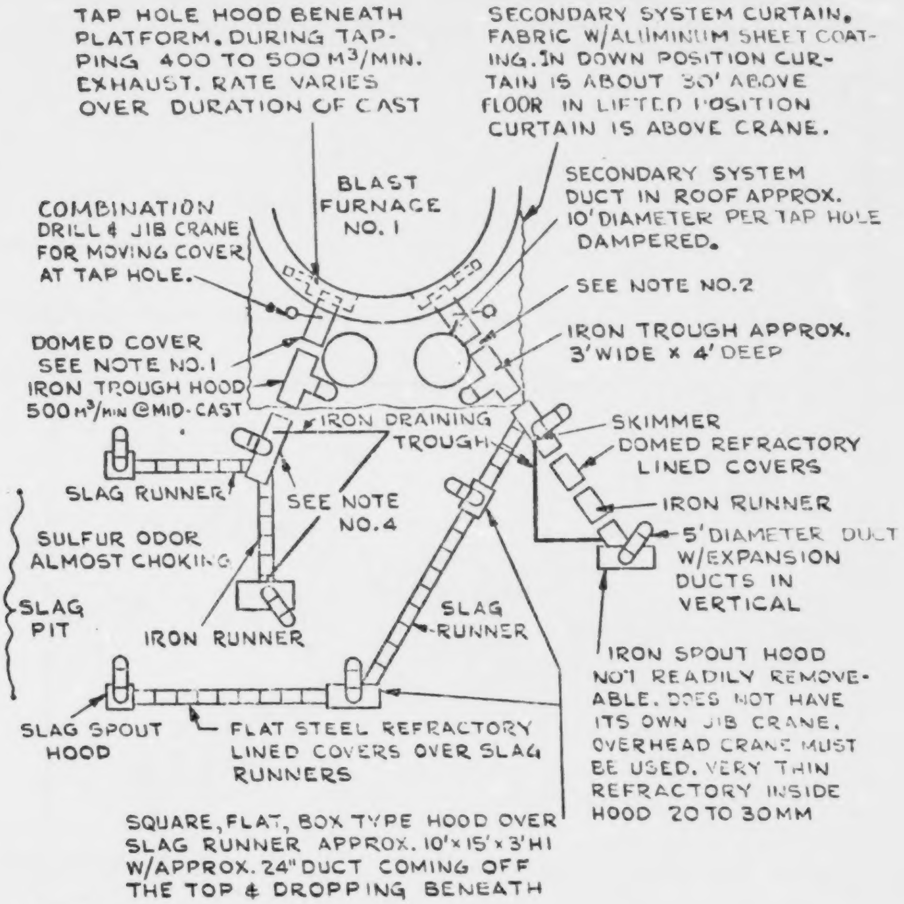

A
A
B
B
NO.2 CAST HOUSE
NO.1 CAST HOUSE
№ 1 BF
4,150 M³
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
C

1 TO 4 AROUND TAP HOLES
5 TO 8 IRON TROUGH
9 TO 12 IRON, SLAG SPOUTS
13 & 14 SLAG TROUGHS
15 & 16 TROUGH REPAIR SHOP
17 & 18 SECONDARY DUST COLLECTOR

A PRIMARY SYSTEM BAG HOUSES 80 M³/SEC EA. (169,500 CFM)
B PRIMARY SYSTEM BAG HOUSES 108 M³/SEC EA. (229,500 CFM)
C SECONDARY SYSTEM BAG HOUSE 333 M³/SEC (706,000 CFM)

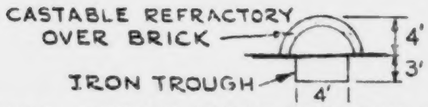
Figure 6-6

NIPPON STEEL CORPORATION OITA WORKS BLAST FURNACE No.1 EMISSION CAPTURE SYSTEM


TAP HOLE HOOD BENEATH PLATFORM. DURING TAPPING 400 TO 500 M³/MIN. EXHAUST. RATE VARIES OVER DURATION OF CAST
SECONDARY SYSTEM CURTAIN, FABRIC W/ALUMINUM SHEET COATING. IN DOWN POSITION CURTAIN IS ABOUT 30' ABOVE FLOOR IN LIFTED POSITION CURTAIN IS ABOVE CRANE.
BLAST FURNACE NO. 1
COMBINATION DRILL & JIB CRANE FOR MOVING COVER AT TAP HOLE.
SECONDARY SYSTEM DUCT IN ROOF APPROX. 10' DIAMETER PER TAP HOLE DAMPERED.
SEE NOTE NO.2
DOMED COVER SEE NOTE NO.1
IRON TROUGH APPROX. 3' WIDE x 4' DEEP
IRON TROUGH HOOD 500 M³/MIN @MID-CAST
IRON DRAINING TROUGH
SKIMMER
DOMED REFRACTORY LINED COVERS
SLAG RUNNER
SEE NOTE NO.4
IRON RUNNER
SULFUR ODOR ALMOST CHOKING
5' DIAMETER DUCT W/EXPANSION DUCTS IN VERTICAL
SLAG PIT
IRON RUNNER
SLAG RUNNER
IRON SPOUT HOOD NOT READILY REMOVEABLE. DOES NOT HAVE ITS OWN JIB CRANE. OVERHEAD CRANE MUST BE USED. VERY THIN REFRACTORY INSIDE HOOD 20 TO 30MM
SLAG SPOUT HOOD
FLAT STEEL REFRACTORY LINED COVERS OVER SLAG RUNNERS
SQUARE, FLAT, BOX TYPE HOOD OVER SLAG RUNNER APPROX. 10'x15'x3'HI W/APPROX. 24" DUCT COMING OFF THE TOP & DROPPING BENEATH

NOTES:

NO.1 DOMED COVER DESIGN IS CRITICAL. THE DOME MUST BE SUFFICIENT TO ALLOW FOR PROPER AMOUNT OF AIR FLOW FOR COOLING.


CASTABLE REFRACTORY OVER BRICK
4'
3'
IRON TROUGH
4'

CONVERSION FACTORS

1 ft. = .305 m

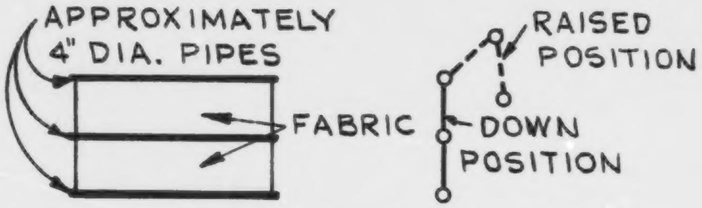
1 m = 25.4 mm

NO.2 APPROX. 3' GAP BETWEEN COVER & HOOD. NO ESCAPING EMISSIONS. DRAFT WAS SUFFICIENT TO PULL EMISSIONS FROM COVER TO THE HOODED SECTION ACROSS THE GAP.

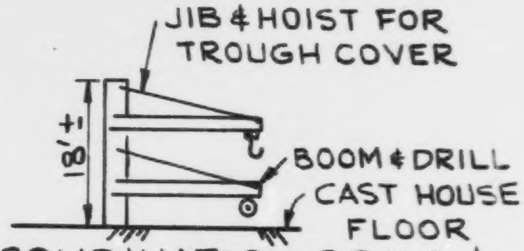
NO.3 SECONDARY SYSTEM CURTAIN IS ACTIVATED ONLY DURING TAPING & PLUGGING. DAMPER IN ROOF OPENED 100%. CURTAIN DROPPED, IT IS DURING THESE TIMES THAT THE IRON THROUGH COVER AT THE TAP HOLE IS REMOVED & EMISSIONS ESCAPE THE PRIMARY SYSTEM

NO.4 SKIMMER HOOD MOVEABLE ON SWING ASM. PIVOTS ABOUT VERTICAL DUCT GOING THROUGH FLOOR 300 TO 400 M³/MIN. EXHAUST DURING MID-CAST.

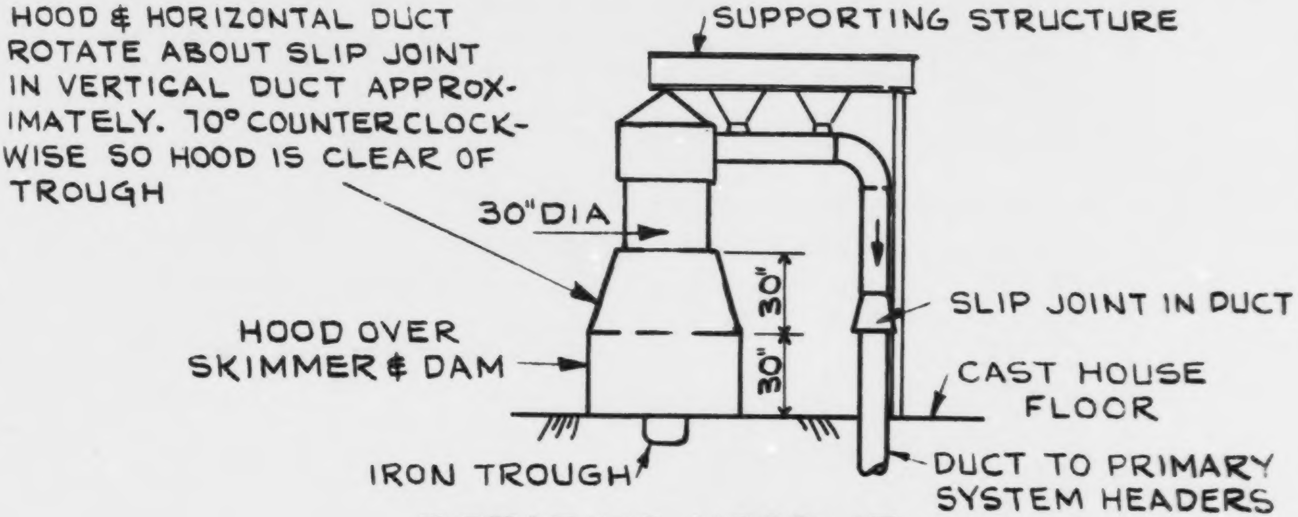
Figure 6-7
NIPPON STEEL CORPORATION - OITA WORKS BLAST FURNACE NO. 1 EMISSION CAPTURE SYSTEM MISCELLANEOUS DETAILS


APPROXIMATELY 4" DIA. PIPES
FABRIC
RAISED POSITION
DOWN POSITION

SECONDARY SYSTEM CURTAIN


JIB & HOIST FOR TROUGH COVER
18'±
BOOM & DRILL
CAST HOUSE FLOOR

COMBINATION DRILL & JIB CRANE

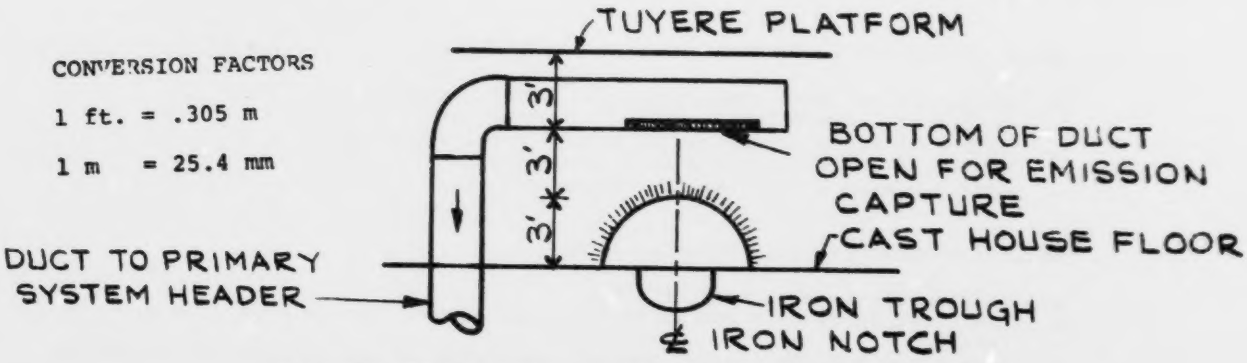

HOOD & HORIZONTAL DUCT ROTATE ABOUT SLIP JOINT IN VERTICAL DUCT APPROXIMATELY. 70° COUNTERCLOCKWISE SO HOOD IS CLEAR OF TROUGH
SUPPORTING STRUCTURE
30"DIA
30"
30"
SLIP JOINT IN DUCT
HOOD OVER SKIMMER & DAM
CAST HOUSE FLOOR
IRON TROUGH
DUCT TO PRIMARY SYSTEM HEADERS

ROTATING HOOD AT SKIMMER & DAM

CONVERSION FACTORS

1 ft. = .305 m

1 m = 25.4 mm


TUYERE PLATFORM
3'
3'
3'
BOTTOM OF DUCT OPEN FOR EMISSION CAPTURE
CAST HOUSE FLOOR
DUCT TO PRIMARY SYSTEM HEADER
IRON TROUGH
℄ IRON NOTCH

FRONT ELEVATION OF BLAST FURNACE TAP HOLE SHOWING IRON NOTCH HOOD

TABLE NO. 6-3

OITA WORKS - BLAST FURNACE NO. 1 AND CAST HOUSE TECHNICAL AND STATISTICAL INFORMATION

1. BLAST FURNACE DATA

a. Furnace inner volume: 4,158 m^3 (146,819 ft^3).
b. Nominal furnace capacity: 10,000 MT/d (11,000 T/D).
c. Number of casts per day: 12 to 15.
d. Hearth diameter: 14 m (46 ft.).
e. Iron notch drill bit size: 40 to 50 mm (1.57 to 1.97 inches).
f. Number of iron notches: four.
g. Number of cinder notches: two.
h. Iron trough (pool) length as made up for cast: 19 m (62 ft.).
i. Iron trough (pool) width as made up for cast: 1200 mm (47.24 inches).
j. Iron trough (pool) depth as made up for cast: 1100 mm (43.31 inches).

2. BLAST FURNACES CURRENT AVERAGE OPERATING STATISTICS AND PRACTICES

a. Duration of cast: 90 to 120 minutes.
b. Oxygen not used to open tap hole.
c. Flushing is not routinely accomplished at cinder notch.
d. Normal blast pressure at beginning of cast: 3.70 Kg. per cm^2 (52.6 psig).
e. Normal blast volume at beginning of cast: 106.67 Nm^3 per sec. (226.000SCFM).
f. Normal blast pressure when tap hole is stopped: 3.70 Kg. per cm^2 (52.6 psig).
g. Iron trough is not normally drained after each cast.
h. Approximately 40 casts occur between iron trough draining.

3. BLAST FURNACE AVERAGE MATERIAL VALUES

a. Slag per ton of hot metal: 290 to 320 Kg per metric ton (580 to 640 lbs. per ton).
b. Coke per ton of hot metal: 395 Kg. per metric ton (790 lbs. per ton).
c. Fuel used at tuyeres: heavy oil.
d. Coke quality, ASTM stability: DI 150/50 = 82%.
e. Amount of fuel at tuyeres: 80 Kg. per metric ton (160 lbs. per ton).
f. Silicon content of hot metal: 0.4%.
g. Sulfur content of hot metal: 0.028%.
h. Manganese content of hot metal: 0.51%.
i. Slag basicity: CaO/SiO$_2$ = 1.24.
j. Sulfur content of slag: 1.00%.
k. Ore in metallic burden: 22.4%.
l. Sinter in metallic burden: 72.4%.
m. Scrap in metallic burden: 0.
n. Pellets in burden: 5.2%.
o. Coke is screened in the stock house.
p. Ore is not screened in the stock house.
q. Sinter is screened in the stock house.
r. Large quantities of coke are not associated with cast.
s. Hot metal temperature: 1510°C (2750°F).

4. BLAST FURNACE IRON TROUGH AND RUNNER MAINTENANCE

a. Frequency of iron runner remaking: 1 per month.
b. Number of casts before relining runners: 100 to 120.
c. Number of casts between major trough repairs: 50 to 60.
d. Number of casts between nominal trough patching: 25 to 30.
e. Material used to line trough: brick and stamp.

5. BLAST FURNACE CAST HOUSE PHYSICAL DATA

a. Tilting spouts are used for iron.
b. The blast furnace is common to two cast houses, one on each side of furnace.
c. Cast house has two cranes, one for each side of the furnace and operating perpendicular to B.F.
d. Adjacent to the cast house are hard slag pits.
e. Hot metal bottles are beneath cast house floor.
f. Cast house floor is open.

Discussions with Nippon Steel personnel and field observations yielded the following salient points.

1. Oita No. 1 B.F. primary collection system maintenance:
    a. First cover over iron trough at tap hole: lining life about 10 days to 2 weeks.
    b. Second cover over iron trough: lining life about 1 month.
    c. Other system covers: almost permanent.
    d. Bottom section of skimmer hood: about 6 months to 1 year.
    e. All covers and hoods are lined with castable refractory over refractory brick.
    f. A special refractory not very high in alumina content is used.
    g. Most refractory problems are associated with spalling.
    h. Tilting spout hood had never been relined.
2. Dust collected by the cast house emission control systems is sent to pug mills for processing followed by sintering. There are three pug mills, one for each of two primary system baghouses and one for the secondary system baghouse. The plant has no precise information on quantities of dust collected.
3. It is the opinion of the Technical Manager of Iron Making at Oita that the following can be factors in the amount of dust generated in the cast house:
    a. Hot metal temperature
    b. Top pressure
    c. Length of tap hole - shorter tap holes generate greater quantities of fugitive emissions then longer tap holes. At Oita tap hole length is kept over 3 meters (10 feet).
    d. Mud permeability and heat resistance
    e. Slag composition

Oita's experience is that hot metal composition does not significantly affect dust generation.

4. Oita normally uses the "soaking bar" technique. It is felt that this technique helps reduce emissions since a more controlled cast is possible. The technique consists of inserting a steel bar partially in a newly plugged hole for the purpose of setting the clay along the length of the tap hole. During tapping, the bar is removed, then the drill increases the length of the hole into the skull. When Oita was visited the "soaking bar" was not being used.

5. Primary system ducts from hoods drop down and run beneath the cast house floor. This approach keeps the cast house relatively free of overhead obstructions, thus allowing a liberal use of hoods.

6. The cast house emission control system originally installed at Oita No. 1 B.F. consisted of only four baghouses. There was a single instance, sometime after the furnace was blown-in, when wet tap hole clay was used with a resulting tap hole blow-out. The blow-out produced voluminous emissions, much of which escaped capture and left the cast house. Because of this incident, the capacity of the secondary system was increased and a fifth baghouse was added.

7. During the inspection visit to Oita No. 1 B.F., the emission capture system was extremely effective with no noticeable escaping emissions. The primary system captured the majority of emissions. Furnace tapping and pouring was witnessed. Plugging was not observed.

8. Hot metal is desulfurized in torpedo cars adjacent to the cast house using a patented Nippon process designated as TDS (torpedo desulfuization system). Basically, the system consists of a rail car mounted device which injects carbide into the torpedo car. During operation, no noticeable emissions were observed.

9. Total Equipment costs (1972 prices) for No. 1 B.F. emission control system were as follows:

Ducts and Hoods	$ 1,800,000
Bag Filters	3,600,000
Fans & Motors	1,300,000
TOTAL	$ 6,700,000

10. Oita No. 2 B.F. has an approximate inner volume of 5,000 M^3 (176,500 ft^3), with 5 tap holes and a cast house emission control system serviced by two baghouses, one

for the primary system and one for the secondary system. Total evacuation volume was not obtained.

Kamaishi Works-

The Kamaishi Works, which was visited on February 20, 1976, is the oldest western style iron and steel facility in Japan, it was first operated in 1857. This works, its site and layout are similar to many of the older U.S. mills. The community abuts the property line. There is little if any room for expansion or growth, and there is a great deal of in-plant congestion. The works is located in the Rikytsu National Park area. This fact undoubtedly adds to the need for implementation of a sound environmental control program.

Following World War II, B.F. #1 was completely rebuilt and blown-in in 1948. B.F. #1 and its cast house were again completely rebuilt in 1975 to include the installation of both primary and secondary cast house emission control systems. The unit was blown-in on January 8, 1976. See Figures 6-8, 6-9 & 6-10 for a schematic diagram and field sketches of the Kamaishi No. 1 B.F. cast house emission control system.

B.F. #2 was relined and retrofitted with cast house emission controls in mid-1974. This cast house was not inspected.

Table 6-4 presents technical and statistical information pertaining to blast furnace No. 1 and its cast house at Kamaishi.

Discussions with Nippon Steel personnel and field observation yielded the following salient points:

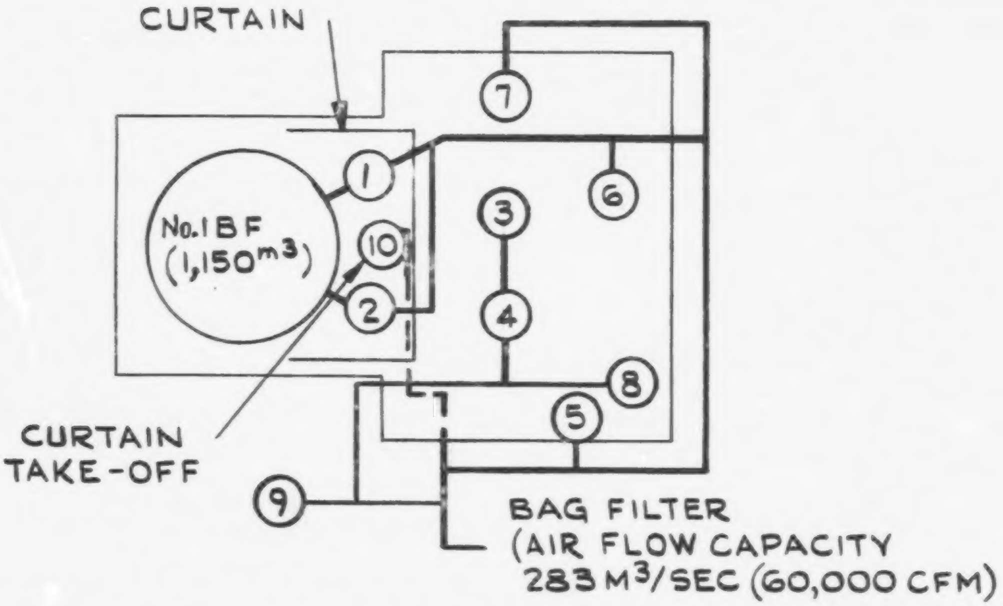
1. Blast furnace cast house #1 has a total primary and secondary evacuation rate equivalent to approximately 50 air changes per hour. 50 air changes per hour is Nippon Steel's general rule-of-thumb for evacuation to be effective in eliminating all visible emissions during a casting cycle.

   Blast furnace cast house #2 has a total primary and secondary evacuation rate equivalent to approximately 20 or 30 air changes per hour.

2. Primary and secondary system throttling dampers can be controlled from either a main control room or from cast house floor panels.

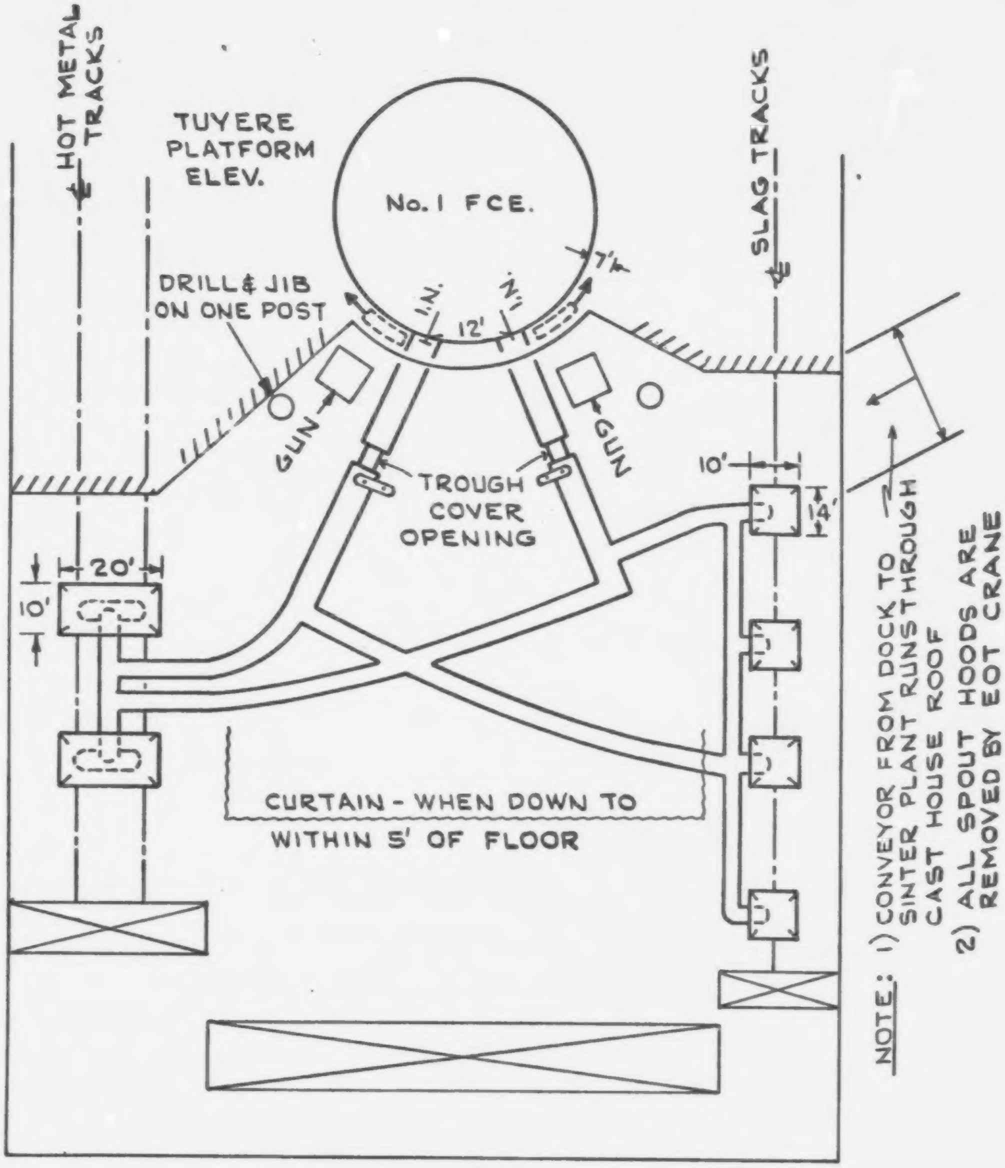
3. B.F. #1 control system employs two fans for use with the single baghouse. One fan has a detachable coupling for energy savings while the second fan always operates.

Figure 6-8
SCHEMATIC DIAGRAM OF CAST HOUSE DUST COLLECTION AT KAMAISHI No.1 B.F. NIPPON STEEL CORPORATION


CURTAIN
No.1 BF
(1,150m3)
1
2
3
4
5
6
7
8
9
10
CURTAIN
TAKE-OFF
BAG FILTER
(AIR FLOW CAPACITY
283 M3/SEC (60,000 CFM)

1&2 TAP HOLES
3&4 IRON TROUGHS
5 IRON SPOUT
6 SLAG TROUGH
7 SLAG SPOUT
8 FE-SI CHARGE
9 DUST DISCHARGER OF DUST COLLECTOR
10 SECONDARY DUST COLLECTOR

Figure 6-9
NIPPON STEEL CORPORATION-KAMAISHI WORKS
BLAST FURNACE NO. 1 EMISSION CAPTURE SYSTEM

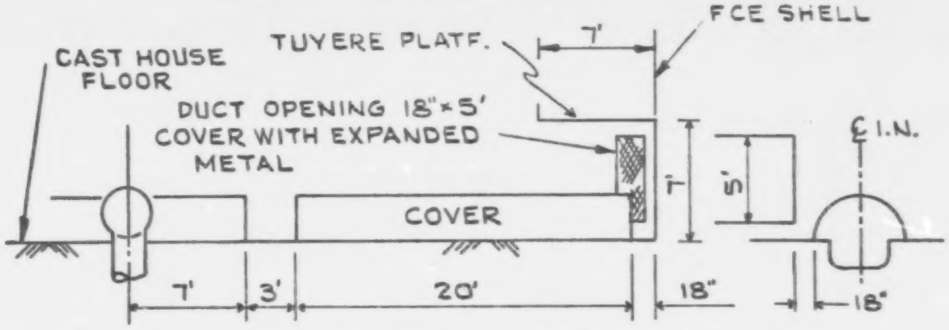

HOT METAL TRACKS
TUYERE PLATFORM ELEV.
No. 1 FCE.
SLAG TRACKS
7'
DRILL & JIB ON ONE POST
12'
GUN
GUN
TROUGH COVER OPENING
10'
14'
20'
10'
CURTAIN - WHEN DOWN TO WITHIN 5' OF FLOOR
NOTE: 1) CONVEYOR FROM DOCK TO SINTER PLANT RUNS THROUGH CAST HOUSE ROOF
2) ALL SPOUT HOODS ARE REMOVED BY EOT CRANE

CONVERSION FACTORS

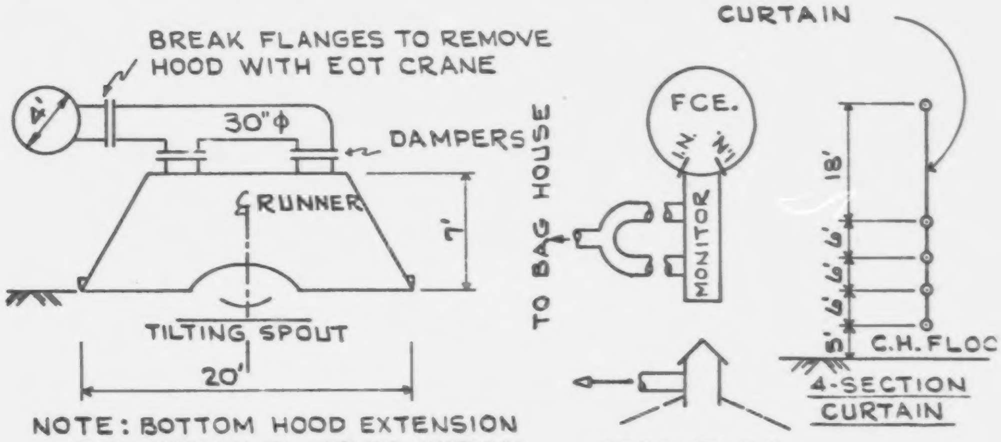
1 ft. = .305 m

1 m = 25.4 mm

Figure 6-10
NIPPON STEEL CORPORATION-KAMAISHI WORKS BLAST FURNACE NO. 1 EMISSION CAPTURE SYSTEM MISCELLANEOUS DETAILS


CAST HOUSE FLOOR
TUYERE PLATF.
7'
FCE SHELL
DUCT OPENING 18"×5' COVER WITH EXPANDED METAL
7'
5'
℄ I.N.
COVER
7'
3'
20'
18"
18"

SECTION THROUGH TROUGH COVER

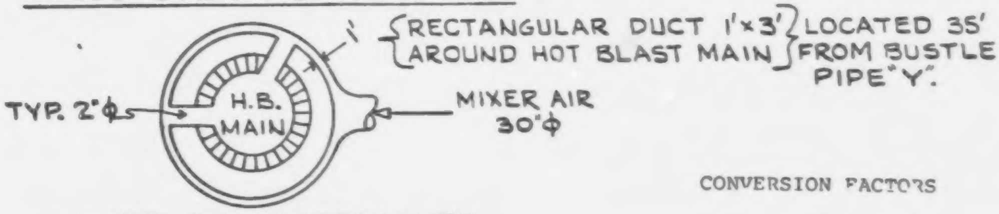

BREAK FLANGES TO REMOVE HOOD WITH EOT CRANE
4'
30"ϕ
DAMPERS
℄ RUNNER
7'
TILTING SPOUT
20'
TO BAG HOUSE
FCE.
I.N.
I.N.
MONITOR
CURTAIN
18'
6'
6'
6'
5'
C.H. FLOC

4-SECTION CURTAIN

NOTE: BOTTOM HOOD EXTENSION GOES BELOW FLOOR TO WITHIN 1' OF HOT METAL CAR

SECONDARY SYSTEM

HOOD OVER TILTING SPOUT


1'
RECTANGULAR DUCT 1'×3' AROUND HOT BLAST MAIN
LOCATED 35' FROM BUSTLE PIPE "Y".
TYP. 2"ϕ
H.B. MAIN
MIXER AIR 30"ϕ

MIXER CONNECTION TO HOT BLAST MAIN

CONVERSION FACTORS

1 ft. = .305 m

1 m = 25.4 mm

TABLE NO. 6-4

KAMAISHI WORKS - BLAST FURNACE NO. 1 AND CAST HOUSE TECHNICAL AND STATISTICAL INFORMATION

1. BLAST FURNACE DATA

a. Furnace inner volume: 1,150 m^3 (40,606 ft^3).
b. Nominal furnace capacity: 1,500 tonnes/D (1,650 T/D).
c. Number of casts per day: 8.
d. Hearth diameter: 8m (26 ft.).
e. Iron notch drill bit size: 50 mm for bit (1.97 inches), 42 mm for rod (1.65 inches).
f. Number of iron notches: two.
g. Number of cinder notches: one.
h. Iron trough (pool) length as made up for cast: No. 1 tap hole, 13 m (43 ft.) No. 2 tap hole, 11 m (36 ft.).
i. Iron trough (pool) width as made up for cast: Outer shell; 1,900 mm (74.80 inches) Inner width; 800 mm (31.50 inches).
j. Iron trough (pool) depth as made up for cast: 790 mm (31.10 inches).

2. BLAST FURNACE CURRENT AVERAGE OPERATING STATISTICS AND PRACTICES

a. Duration of cast: approximately 100 minutes.
b. Oxygen is occasionally used to open tap hole.
c. Flushing is not routinely accomplished at cinder notch.
d. Normal blast pressure at beginning of cast: 1.103 E + 04 Pa (22.75 psig).
e. Normal blast volume at beginning of cast: 25 Nm^3 per sec. (53,000 SCFM).
f. Normal blast pressure when tap hole is stopped: 1.103 E + 04 Pa (22.75 psig).

g. Iron trough is not normally drained after each cast.
h. Iron trough is drained several times a month.

3. BLAST FURNACE AVERAGE MATERIAL VALUES

a. Slag per ton of hot metal: 340 Kg. per metric ton (680 lbs. per ton).
b. Coke per ton of hot metal: 520 Kg. per metric ton (1040 lbs. per ton).
c. Fuel used at tuyeres: tar or heavy oil.
d. Coke quality, ASTM stability: DI 150/50 = 82%.
e. Amount of fuel at tuyeres: 4,000 1/H/18 tuyeres.
f. Silicon content of hot metal: 1.8 to 2.2% (foundry).
g. Sulfur content of hot metal: 0.030%.
h. Manganese content of hot metal: 0.50%.
i. Slag basicity: CaO/SiO_2: 1.10.
j. Sulfur content of slag: 0.6%.
k. Ore in metallic burden: 20%.
l. Sinter in metallic burden: 60%.
m. Scrap in metallic burden: 0.
n. Pellets in burden: 20%.
o. Coke is screened in stock house.
p. Ore is not screened in stock house.
q. Sinter is screened in stock house.
r. Large quantities of coke are not associated with cast.
s. Hot metal temperature: 1500°C (2732°F).

4. BLAST FURNACE IRON TROUGH AND RUNNER MAINTENANCE

Kamaishi No. 1 B.F. iron trough and runner maintenance had not been assessed because furnace was recently blown-in.

5. BLAST FURNACE CAST HOUSE PHYSICAL DATA

a. Tilting spouts are used for iron.
b. Blast furnace serves one cast house.
c. Cast house has three cranes that operate perpendicular to furnace.
d. Slag pots are used.
e. Hot metal bottles are beneath cast house floor.
f. Cast house floor is open.

4. The secondary system curtain is dropped to a level about 1 1/2 meters (4 1/2 feet) above the floor during tapping and plugging. During the visit to cast house #1 only casting and plugging were witnessed, not tapping. During casting, the secondary system curtain was kept down.

5. When B.F. #1 was rebuilt, the cast house roof had to be raised several meters to make room for the secondary system curtain. Also, the cast house floor and foundations were reworked to allow for the installation of beneath-the-floor primary system ductwork. The rebuild was completed in 130 days. Additionally, space limitations outside the cast house did not allow Nippon Steel to install separate baghouses for the primary and secondary systems. There is only one baghouse which is used for both systems.

6. The Kamaishi cast house emission control system has four (4) operating modes:

    a. Tapping - Curtain lowered, secondary system most effective, primary systems least effective.

    b. Casting - Curtain lifted, secondary system throttled, primary system at maximum exhaust.

    c. Plugging - Same as tapping.

    d. Melting only - curtain lifted, one fan disengaged from motor, second fan throttled so that total system may be only 30% of max. capacity.

7. According to the Deputy General Manager of Iron Making Department, the secondary system is not as important as the primary system. It is his estimate that 80 to 90% of the dust is captured by the primary system.. This must be a rough estimate since there is only one baghouse for both the primary and secondary systems.

8. Kamaishi uses the soaking bar technique - approx. 2 meters (6.56 feet) in length.

9. The tap hole drilling angle is approx. 12°.

10. Furnace cinder notch is used only in emergencies.

11. There was no evidence of hot metal desulfurization in the vicinity of the cast house.

12. B.F. #1 primarily produces foundry pig iron with approximately 2% silica and approximately 3 % sulfur in

the hot metal. Because this metal is relatively high in silica, metal sticking to runners is common. Special considerations such as ease of removal were necessary in the design of B.F. #1 iron trough and runner covers and hoods.

13. B.F. #2 produces iron primarily for the B.O.F.

14. The baghouse consists of "Teflon" woven cloth fabric, maximum temperature 110°C. Bags are 10 meters (32.8 feet) in length and 202 mm. (8 inches) in diameter. Air-to-cloth ratio is 1 to 1 on a meters basis, 1 meter per minute (3.28 feet/min.). Approximate gas temperature entering baghouse is 60°C (140°F). Approximately 4,000 tonnes per month of dust comes from the B.F. No. 1 baghouse and the B.F. thickeners. The evacuation capability of the primary and secondary systems totals 283 cubic meters per second. (600,000 CFM).

15. B.F. #1 Cast House Emission Control System Costs: 1975 Prices

Ducts and Hoods	$ 600,000
Bag Filters	1,200,000
Fans and Motors	500,000
TOTAL	$2,300,000

EUROPEAN TECHNOLOGY

Selected European blast furnace operations were visited to determine the extent of European achievement in controlling emissions from casting hot metal. Installations visited were:

1. British Steel Corporation's new Redcar installation at Teeside, Middleborough, England, is about 93 kilometers (150 miles) north of London on the east coast of England. Included in this visit were discussions of the British Steel's Llanwern Plant in Wales.

2. Italsiders' Taranto Works in Southern Italy.

3. Mannesmann Aktiengesellschaft Huttenwerke at Duisburg Huckingen, West Germany which is the steel producing site for Mannesmann AG.

4. USINOR (Union Sederurgigue du Nord et de l' est de la France) at Dunkerque, France.

These sites were the only European plants found in our literature search to either have emission controls installed or being designed. A French plant at Solmer, Marseilles, also believed to have controls, was not visited due to schedule difficulties.

The only plant with an operating emission control system was at Taranto, Italy. This plant used a fabric filter with polyester bags. The other plants were either new plants, not completed, or, as in the case of Dunkerque, had no filters or gas cleaning equipment.

British Steel Corporation South Teeside Works, Redcar, England

Redcar #1 B.F. is under construction at a site where a new integrated steel plant is being developed as part of a ten year, 3-billion-dollar expansion program. Redcar #1 B.F. will be completed about 1978. The future will see a total of three new 10,000 tonnes per day blast furnaces, and three new BOF, coke ovens, rolling mills, etc., giving the operation a 10 to 12 million annual tonne steelmaking facility. British steelmaking has been nationalized in an effort to make it competitive with U.S., Japan and Russia.

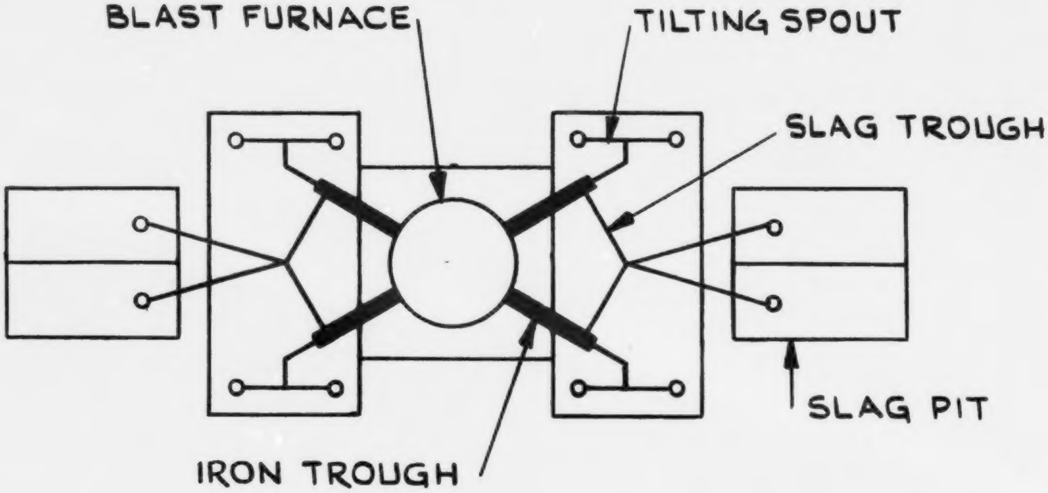
The plan view of the cast house of the #1 blast furnace at Redcar is shown on Figure 6-11. Technical specifications for the furnace are presented in Table 6-5. At Redcar #1, four iron notches are provided, with removable iron troughs, each cast house having an overhead crane serving two runners. Each hot metal runner discharges via a tilting spout to either of two 450 tonnes hot metal mixer ladles, and each cast house is designed to accommodate future hot metal ladles of up to 600 tonnes capacity.

One emergency slag notch is installed and slag from each cast house discharges into twin slag pits. Provision was made for the future installation of a slag granulating plant.

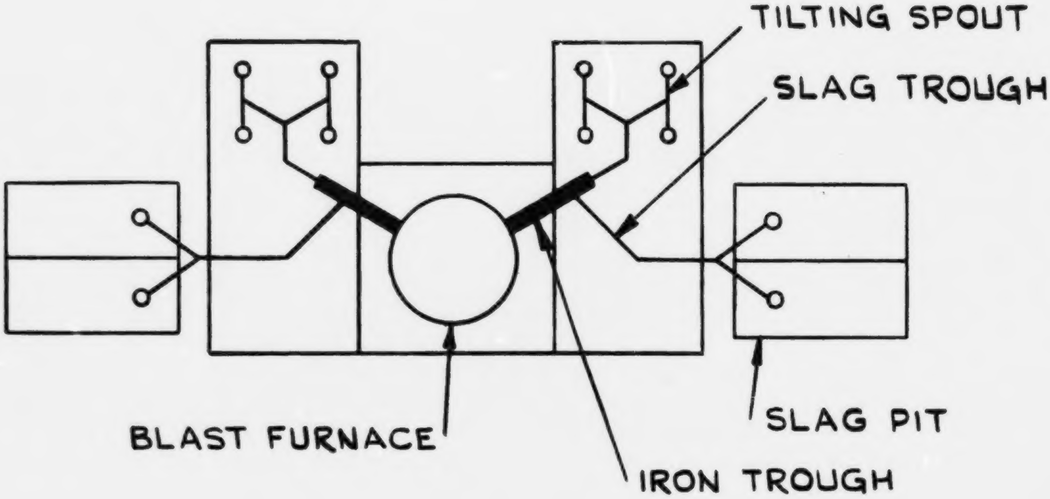
The two cast houses extend out to provide additional area to serve for main and tilting iron runner maintenance. Each cast house crane is designed to handle the main runner with a single lift of approximately 85 tonnes. The system of removable runners enables all wrecking and relining to be undertaken adjacent to, but remote from, the main casting area, which will reduce notch down time.

The iron trough is designed with a slope of 1°, which permits the retention of a deep pool of liquid iron in the area where the flow of iron impinges on the pool, and thus provides lining protection. Heat retention covers positioned over the trough enable the iron to remain liquid between casts. Instead of draining the iron pool after every cast, which is common practice in Europe, draining is undertaken after approximately 15,000 tonnes of iron are produced and subsequently at additional 5,000 tonnes intervals. Using this technique, runner lining life in excess of 50,000 tonnes is achieved. The distance of 17 meters

Figure 6-11
PLAN VIEW OF CAST HOUSE FLOOR AT B.S.C. REDCAR AND LLANWERN BLAST FURNACES


BLAST FURNACE
TILTING SPOUT
SLAG TROUGH
SLAG PIT
IRON TROUGH

RED CAR #1


TILTING SPOUT
SLAG TROUGH
BLAST FURNACE
SLAG PIT
IRON TROUGH

LLANWERN #3

TABLE 6-5

EUROPEAN PLANT STATISTICS

Item	Unit	Redcar #1	Italsider Taranto #5	Mannesmann Huckingen A	Usinor Dunkirque #4
Iron Production	t/Day	10000	8500	5000	10000
Coke Rate	Kg/t	450	440	-	485
Oil Rate	Kg/t	100	45	-	120
Burden	%	60 Sin-40P	85 Sin-15P	-	74 Sin-16P
Hearth Diameter	M	14	14	10.4	14.2
Working Volume	M^3	3894	3358	-	3765
No. of Cast Houses	-	2	2	-	4
No. of Iron Notches	-	4	4	-	2
No. of Slag Notches	-	1	1	-	1
Runner Type	-	Removable	Removable	Removable	Removable
Pouring Spout	-	Tilting	Tilting	Tilting	Tilting
Fume Control	-	Future	Baghouse	Future	None
Taphole Diameter	MM	-	76	-	-
Blast Volume	NM^3/M	8700	5916	-	6750
Blast Pressure	bar g	2.5	3.45	-	2.5
Blast Temperature	°C	1340	1514	-	1300
No. of Stoves	-	3	4	-	4
Angle of Tap hole	Degrees	10	12	-	6
Sulfur	%	-	0.24	-	-
Silicon	%	-	0.60	-	-
Control Volume	M^3/Sec.	250	167	278	250
Oxygen	%	-	3	4	-
Trough Hood Repair	Days	-	20	-	8
Slag	-	Pit	Pit	-	-
Iron Trough Length	M	17	-	-	15
Runner Volume	M^3/Sec.	183	-	-	-
No. Casts/Day	-	-	12	-	8
Stockhouse Vent.	M^3/Sec.	-	-	-	11
Ladles	t	650	250	Open Pots	130 (Pots)
Air Curtains	M^3/Sec	-	-	None	50
Iron Spout	M^3/Sec	-	-	69	50
Slag Spout	M^3/Sec.	-	-	41	-
Tap Hole Side Draft	M^3/Sec.	-	-	208	No Cleaning
Over Trough	M^3/Sec.	-	-	70	-
Runners and Spouts	M^3/Sec.	-	-	108	-

(56 foot) between tap hole and skimmer is sufficient, under high blast pressure operation, to provide sufficient dwell time for adequate separation of slag from iron.

In order to establish an improved working environment, dust and fume extraction systems will be installed in the stock house and cast houses. Iron and slag runners will be provided with a system of covered hoods and a protective curtain will be installed over each iron notch to ensure effective fume removal. Collected fume will be removed from the air stream by filters prior to discharge to the atmosphere.

At Redcar, discussions between B.S.C. and the local Alkali Inspectors are still in progress to insure that the level of noise and pollution emission conforms to standards.

The emission control system of the cast house was designed by Nippon Steel, and modified by Davy Ashmore. A bag filter is being considered at this time but some concern is being shown because of the possibility of sparks reaching the bags. Davy Ashmore has designed a spark arrestor in an attempt to eliminate this problem. Ventilation rate for one tap hole runner system is 183 cubic meters per second (338,000 cfm). Tilting spouts will be used with hooding. Individual point ventilation rates from B.S.C. were not available.

The important feature of this plant design is the emphasis placed on equipment to reduce fume emission and noise.

Taranto, Italy Italsider S.P.A.

Italsider's Taranto Works, the Southern Italy tube, plate and sheet producer, ranks as Western Europe's largest single steel mill. Annual capacity is 10 1/2 million tonnes. Special government grants designed to promote industrial development in southern Italy have provided most of the financing for the huge mill. The Taranto Works draws fresh water from two small local rivers and a mountain reservoir, then mixes it with desalted sea water for use in various production units. The outflow is treated before being returned to the Mediterranean.

There is a serious effort being made to ensure air quality. Taranto's newest blast furnace, B.F. #5, collects and filters fumes from almost every conceivable source. The only visible smoke, in or around the unit, comes from the trash discarded into slag runners and burned during a cast.

The community of Taranto, which crowds approximately 135,000 people into it's narrow streets and alleys, wants to hold down the possibility of future contamination of it's air and water by insisting that the steel plant stay within present emission and effluent limits.

In the spring of 1976, Taranto was operating at about 80% of its capacity. One vessel at Taranto's #1 BOF shop was idle, reducing its number of heats per day output from a maximum of 90 to between 70 and 75. Taranto has five blast furnaces-- two 10.2 meter hearth diameter furnaces, two 10.6 meter (35 feet) hearth diameter, and one 14 meter (46 feet) hearth diameter furnace. Number 1 blast furnace was down for relining.

Taranto's No. 5 blast furnace is the stellar attraction of all the new facilities that came on stream in the latter stages of the new expansion. Boasting a 14 meter (46 feet) hearth diameter and a daily hot metal capacity of 10,000 tonnes, it ranks as the worlds' fifth largest blast furnace. The furnace is expected to level out at 11,000 tonnes daily as its operators gain experience.

Designed and built by an arm of the Felsider group with the assistance of Nippon Steel Engineers, No. 5 has two cast houses and four tap holes, any two of which can be used simultaneously to achieve what amounts to continuous hot metal casting. Charging is accomplished by conveyors from computer controlled bins. Closed circuit television keeps tabs on the materials feed to the furnace.

The 4 bell top is designed to operate at a maximum pressure of 2.452 E + 05 Pa (35.5 psig). Actual operating pressure was about 1.96 E + 05 Pa (28.4 psig).

Thirty-six tuyeres deliver hot blast from four externally fired stoves at 1200° C (2192° F). Design limit is 117 cubic meters per second (247,000 CFM)

The blast is enriched with oxygen at a rate of 3%. Coke consumption is 440 to 450 kilograms per metric ton of hot metal, and oil is injected at the tuyeres at the rate of 35 to 45 kilograms per tonne of hot metal.

The free standing, externally supported furnace also features plate stave cooling, moveable throat armor and moveable runners. Each tap hole casting station and slag outlet is hooded and vented to fans which pull all the fumes through a baghouse. The burden consists of 85% sinter and 15% pellets. No coke messes have been experienced. The hot metal at a temperature of 1514° centigrade (2757°F) has an analysis of .60% silicon and .024% sulfur. Of the four tap holes, No. 1 and No. 3 are used for two days and then No. 2 and No. 4 are used for the next two days. The baghouse, which filters 167 cubic meters per second (353,000 CFM), has 1,000 bags of polyester cloth which are 300 millimeters (11.8 inches) in diameter and 10 meters (32.8 feet) high. The furnace casts 12 times per day into 260 tonne torpedo cars driven with electric locomotives. There is also a desulfurization facility at the site.

At the time of the visit to the cast house of No. 5 blast furnace, the pouring spout ventilation was not operating due to a closed valve in the duct, and heavy concentrations of emissions were escaping around the pouring spout. The runners were hooded completely, but some of the sections had been removed and their use discontinued because of unacceptable maintenance created by erosion of the upper edges of the runners by high velocity of air through the hoods. There was some improvised corregated sheeting at the tap hole to assist the side draft hoods. The ventilation system in the cast house was doing a reasonably good job, except for a malfunction when the damper closed at the iron ladle exhaust take-off.

Huckingen, Germany

There are five blast furnaces at Mannesmann-- #3, #4, #5, #6, &A. A mock-up of "A" furnace emission control system was available for inspection. The control system is scheduled to be in operation in July, 1977. The "A" furnace has a 10.4 meter hearth and produces around 5,000 metric tons per day of hot metal. Mannesmann's engineers were very much interested in discussing baghouses because they did not feel that they could count on long life from cloth. They have had trouble with baghouses in other installations and would prefer an electrostatic precipitator.

The "A" furnace at Huckingen, Dusseldorf will have a solid platform 3 to 3.4 M. (10 to 11 feet) above the tap hole, with a removable grating at the tap hole area. The proposed ventilation rates in the cast house include 69 cubic meters per second (147,000 CFM) each at the tap hole, trough and skimmer; and 28 cubic meters per second at the spout (59,000 CFM). Total ventilation capacity will be 278 cubic meters per second (588,500 CFM). The model displayed had side draft hoods directly at the tap hole. A hood pivoted on a stanchion directly into the hot metal trough area, with a side draft hood at the pouring spouts. Curtain ventilation was not being considered. Also, runner emissions will not be captured because they are considered insignificant.

The No. 6 furnace produces about 2,000 tonnes per day with a 7 meter (23 feet) hearth diameter. The cast house consisted only of a roof and was totally open at the sides; this diluted casting fugitive emissions so thoroughly that they were hardly noticeable from outside the cast house. However, tapping emissions were quite noticeable.

The government has spent 70 million marks at Huckingen for ambient pollution studies.

The furnaces will produce about 10,000 tonnes per day with either #3, #4, #5, or #6 down. The company produces four million metric tons per year of steel for tubing only.

Usinor Steel, Dunkerque, France

The steel works at Dunkerque is one of Europe's leading steel producing centers. The eight million tonnes per year facility has four blast furnaces, including a 14.2 meter (46.6 feet) hearth diameter furnace capable of producing 10,000 tonnes per day of hot metal.

Dunkerque upgrades nearly all of the million of tons of raw materials it uses each year. To insure uniform blast furnace charges, ores are crushed, screened and blended before sintering (sintering capacity is sufficient to provide 87.5% of the burden material going into blast furnaces 1,2, and 3 and up to 74% of the ore feed at number 4). Coke and limestone are also screened.

The No. 4 blast furnace was blown in on May 1, 1973 and, with it's auxiliaries, occupies 20 acres of plant property. The furnace casts 7 to 8 times a day; has a conveyor charging system, a coke rate of 485 kilograms per metric ton of iron (970 lbs per ton), a fuel injection rate of 120 kilograms per metric ton (240 lbs. per ton), a working volume of 3,765 cubic meters (133,000 cubic feet), and incorporates 2 cast houses. Each cast house is vented with 250 cubic meter per second (530,000 CFM) volume. There are a total of 10 ventilation points with five points of 50 cubic meters per second (106,000 CFM) in each cast house. Breakdown of the ventilation points is as follows: from the curtain there are two take off points of 25 cubic meters per second each (53,000 CFM); from the pouring spout there are two side draft hoods of 50 cubic meters per second (106,000 CFM) each or 100 cubic meters per second (212,000 CFM) total. Fume was escaping from these hoods. At the tap hole hooding (which was very ineffective) there were two vents at 50 cubic meters per second (106,000 CFM) each or 100 cubic meters per second (212,000 CFM) total. Air curtains are vented with an additional 65 cubic meters per second per cast house (138,000 CFM). The furnace has a trough 15 meters (49 feet) in length for the iron pool and a 6 degree angle tap hole. The furnace is cast from opposing tap holes, one 41 cm. (16 inches) above the other. Both the iron and slag are transferred to 130 tonne open ladles. Torpedo cars will replace the open ladles in 1979. Other vital statistics are given in Table 6-5.

The principal reason for the visit to Dunkerque was to obtain information on a test that was carried out on the No. 2 blast furnace using high sulfur fuel oil as opposed to low sulfur fuel oil at the tuyeres. The usual No. 2 blast furnace operation which utilizes 1% sulfur fuel oil, was considered as a base case for the test period. Table 6-6 gives mean values which were

FRENCH TECHNOLOGY

TABLE 6-6

Results of Comparative Tests on the Injection of Auxilliary Fuel with 1% and 3.3% sulfur by weight.

Item	Terms	1%S	3.3%S
Coke-S	%	0.68	0.65
Fuel-S	%	1.00	3.30
Coke	Kg/tHM	420	420
Fuel	Kg/tHM	70	70
Coke & Fuel Rate	Kg/tHM	490	490
Slag-Basicity	CaO/SiO_2	1.11	1.13
Slag-S	%	1.15	1.52
Hot Metal-Si	%	0.68	0.65
Hot Metal-S	%	0.025	0.040
Hot Metal-Mn	%	0.622	0.670
Sulfur in Burden	Kg/tHM	3.65	5.13
Sulfur in Products	-	-	-
a. Slag	Kg/tHM	3.22	4.26
b. Hot Metal	Kg/tHM	0.25	0.40
c. Top Dust	Kg/tHM	0.04	0.06
d. Top Gas	Kg/tHM	0.05	0.05
e. Runner Gas	Kg/tHM	0.04	0.05
Total Sulfur	Kg/tHM	3.60	4.82
Emissions, Ave. (from Slag)	g/NM^3	0.20	0.20

taken under steady state conditions. In discussions with the engineer who conducted the testing, it appears that the errors introduced by coke, fuel and slag flow evaluation, and by sulfur measurements leave some doubt as to the test results.

Emissions from slag during tapping were periodically measured at a point .5 meters (1.64 feet) above the slag runner by means of a hood which was fitted to the runner geometry. The sampling velocity under the hood was adjusted to correspond with that due to free convection over the runner in order to obtain a true estimate of the sulfur content of the air in the immediate vicinity of the slag runner. It was found that sulfur concentrations in the hood increased considerably as tapping proceeded. The increase appeared to be associated with an increase in the level of slag in the runner as tapping proceeded, or, more likely, because of more efficient contact between the slag and air in a full runner. Overall, the emissions from the slag corresponded to a sulfur loss of 250 to 200 grams per tonne of slag. This general level was confirmed by a comparison of slag analysis at the tap hole and at the end of the runner. Analysis did not show any increase in sulfur content in either the top gas or runner gas when the high sulfur fuel was injected.

Replacement of 1% with a 3.3% sulfur content in the fuel oil lead to an increase of the hot metal sulfur content from .025% to .040%, but higher sulfur content did not increase the emission of sulfur compounds to the atmosphere. Systematic slag samples were taken during casting, and variations up to .2% sulfur were noticed in the same batch. For instance, during casting, suflur content of the slag would vary from 1.4% at the beginning to 1.6% at the end.

The No. 2 furnace on which the test was run has a hearth diameter of 9.5 meters (31.2 feet) and a capacity of 1600 cubic meters (56,500 cubic feet). Production is approximately 3,000 tonnes (3300 tons) per day of hot metal, with a coke rate of 420 kilograms per tonne of hot metal (840 lbs. per ton). The carbon content of the hot metal is about 4.6%.

LITERATURE SEARCH

An extensive literature search was made to uncover any background information that might exist pertaining to the state-of-the-art of cast house emissions control. It appears that if any research or development work has been done on the control of cast house emissions it has not been formally reported or presented as a technical paper. Government computer services referring to blast furnaces and control of pollution all centered around top gas cleaning, but did not refer to cast house emissions. A list of periodicals and reference books appears in the bibliography.

Visits were made to technical libraries including the Carnegie Library of Pittsburgh and Lehigh University Library at Bethlehem, Pa. These libraries contain most of the literature and references to iron making. Most of the abstracts examined made only vague references to pollution. Some of the foreign suggestions were inappropriate, such as the Russian proposal to wash down the roof of the cast house to recover the effluents.

Based on the results of the literature search, it appears that this is the first indepth study that has been published on cast house emission control. Studies generally were not continued to a quantitative or conclusive phase and thus are not recorded.

SECTION 7

CONCEPT DESIGNS FOR EMISSION CONTROL ON EXISTING BLAST FURNACE CAST HOUSES

The following conceptual designs (or combination of designs) are types of emission control systems which could be applied to existing blast furnace cast houses. These designs include a method to satisfy conditions up to 100% emission collection (which would be a system of total evacuation of the cast house). The air volumes range from 94 m^3/sec. (200,000 CFM) to 472 m^3/sec. (1,000,000 CFM).

In most cases, concepts advanced have not been proven through demonstration activities but are set forth as ideas or suggested methods to follow. Building evacuation is in routine use at DOFASCO while partial control of tap hole and trough area emissions is routinely employed in Japan. Tests by Bethlehem Steel Corp. on retrofitting partial control techniques, while promising, indicate a need for a further development effort.

NO POLLUTION CONTROL SYSTEM INSTALLATION BUT THE APPLICATION OF PROCESS REVISIONS AND PROCESS CONTROL MODIFICATIONS TO PRESENT PRACTICES

Based upon B.E.E. observations of basic iron casting at 16 blast furnaces in this country it can be stated that the fume quantities generated at the iron trough and runners can vary substantially between cast houses. The tap hole, trough and runner lining materials as well as hot metal chemistry and degree of hot metal cooling are the reasons for the observed variations in fume generation. Discussions with A.P. Green and North American Refractories has substantiated our suspicion that the lining materials used do have an effect on the quantities of fume generated within the cast house. Quantitative data however, is not known to exist. AISI believes that even if all emissions from tap hole materials and trough and runner lining materials could be eliminated by substituting different materials, a substantial fraction of the present casting emissions will still occur, namely those evolving from the molten iron and slag.

High-purity, tap hole ramming castables with a high alumina content are suspected of producing less emissions than low alumina materials. Additionally, the tap hole refractory should be capable of resisting carbon monoxide disintegration as encountered in a reducing atmosphere. Temperature resistance to 1900°C (3452 °F) and an ability to withstand the severe thermal shock of being heated and cooled rapidly must be considered. The dimensional stability of the tap hole is very important to limiting emissions. A poor material will abrade due to the passage of slag and other abrasive elements, causing enlargement of the tap hole and, consequently, the ejection of particulate matter. The ramming characteristics of the refractory are also important to the forming of a strong, uniform plug. Internal moisture should be easily removed, and an impervious barrier to gases must be formed at set-up. Manufacturers are researching materials in an attempt to develop resistant castables which can decrease the emissions caused by this source.

Trough and runner lining materials vary from plant to plant and a difference in fume emissions from this source is apparent. A normal bottom lining of 830 T Nalram, 40% alumina and 19% graphite with a side lining of 67% silica, 7% alumina, 15% carbon produced very little fume during casting at one site. However, there are many other variables in the hot metal chemistry and operating procedures so that a clear conclusion cannot be made without further study.

It appears that if the runners are dry and the silica sand has been applied properly, the emissions from the runner sides are minimal. The use of coke breeze increases the emissions. If the runners are short to reduce metal cooling, and the make-up materials are applied properly, a decided reduction of fumes can be achieved.

The emissions from the hot metal in the trough and runners during cast are greatly increased when the hot metal temperature decreases from a normal temperature of 1454°C to 1399°C (2650°F to 2550°F). This decrease in hot metal temperature is a result of a decrease in hearth temperature. The hearth temperature is a function of the flame temperature maintained at the tuyeres, which is usually about 1954°C (3550°F). The flame temperature is controlled by the hot blast temperature, fuel injection rate, moisture injection rate, and oxygen injection rate. A change in the flame temperature at the tuyeres is influenced by a variance in the ratio of carbon to iron-bearing materials. A deviation in the chemistry of the burden materials and/or a scab build-up on the furnace walls peeling off and dropping into the hearth will cause a decreased hearth temperature, with a resultant decreased hot metal temperature.

Improvements in burden sizing, quality and control could reduce the casting emissions. Coke stability and the use of suitable pellets are major factors to be considered as well as the pre-reduction process which has considerable merit.

Use of the "soaking bar" technique applied in some Japanese blast furnace operations has some merit in reducing tapping emissions; to what extent, however, is not known. The principle of this practice is to set the tap hole clay with heat, which gives the tap hole added erosion and thermal resistance. A steel bar or rod is set in the tap hole at the time of plugging. It is then removed at the time of casting by a special reversing action of the drill, followed by tap hole drilling into the skull.

Hearth pressure, wind volumes and temperature of the hot blast must be considered as important control factors in reducing pollution.

Supplementary fuel types, quantities and usage should be considered along with geometric studies of iron trough configuration, and the length and shape of both slag and hot metal runners.

All of the above factors cannot be properly analyzed in this study. An additional research program will be necessary to properly evaluate the potential and feasibility of controlling these factors to limit emissions.

Torpedo ladles, or hot metal bottles, are sometimes brought into the cast house from outside areas where they have cooled and picked up moisture. When the hot metal from the pouring spout contacts the moisture, a violent reaction occurs, sending large plumes of fume laden steam into the atmosphere. This condition can be avoided by preheating the cars. An enclosure could be provided, and a blast furnace gas lance could be used to condition the ladles before filling.

These modifications to materials and operating procedures would provide some cast house emission control with little or no increase in energy consumption, and, therefore, would not increase pollution from energy producing sources. The economics have not been reported in this study because of the lack of specific knowledge of furnace operating technique modifications that would affect emissions.

PARTIAL CONTROL OF CAST HOUSE EMISSIONS WITH NO CHANGES IN PROCESS

Partial control could be obtained by capturing that portion of fume that escapes from the tap hole and iron trough area in an overhead, curtain-type, retractable enclosure. The concentration of particulate matter emanating from this zone is estimated to vary from 50% to 80% of the total emissions from casting. Some concept designs which could be considered for the application of a partial enclosure to capture the fumes generated in the area of the tap hole and iron trough are shown on Figures Nos. 7-1 thru 7-12. These designs have not been demonstrated as being feasible on single tap hole furnaces

Figures 7-1, 7-2 and 7-3 are three sketched views of a hood concept utilizing telescoping metal plates as shown on figure 7-4. These are loose fitting sections of reinforced plates, raised and lowered on three sides to form a hood or enclosure. It should be possible to design this type of arrangement for effective operation. Negative factors are weight, leakage, and malfunctions due to buildup of dirt. A compressed air header with properly positioned vents could direct the fume away from the space between the bustle pipe and furnace.

Figure 7-5 depicts the roll-up curtain with the mandrel located in the trusses. The curtain would be fabricated from a high temperature 1093°C (2000°F) textile material strengthened by inconel wire. A guy wire fixes the rear edge, and the forward edges are interlocked at the bottom. The curtain would drop to a selected height above the mud gun and drill to allow for free operation at the tap hole. Negative factors are mostly ones of safety, such as worker reluctance to work in the area near the curtains in case of malfunction or failure of material.

Figure 7-6 illustrates the method Carborundum recommends be used with its "fiberfrax" material. Roll-up would be achieved by cables around the bottom pipe. This would minimize the safety problems because the curtain material would not be subject to the total weight of the assembly.

Figure 7-7 is a scheme that would draw the flexible curtain up between the crane and trusses and eliminate roll-up problems. Negative factors are similar to those discussed for Figure 7-5.

Figure 7-8 shows a method utilizing metal slats which are drawn up similar to venetian blinds. This method could be rendered ineffective by a build-up of dust that could cause difficulty in raising the curtain, and also considerable leakage would occur around the slats.

Figure 7-9 is an arrangement of metal plates, connected by loose hinges, which are folded under the trusses by cables and winches. This method, while secure, would leak considerably because of the spaces between the plates.

Figure 7-10 is similar to Figure 7-9 except larger plates are used if the space between the crane and truss is adequate. The negative factors are the same as those for Figure 7-9; buckling would have to be eliminated by reinforcement, which would increase the weight considerably.

Figure 7-11 is a plan similar to Figure 7-1 except that the partial hood would be used for multiple tap hole furnaces. Since only one tap hole would be casting at a given time, the volume of vented air could remain the same as a single tap hole furnace if dampers are used to control the flow. The idle curtain could be drawn up into the truss area.

Figure 7-1
PLAN VIEW SINGLE TAP HOLE FURNACE PARTIAL EMISSION CONTROL CONCEPT

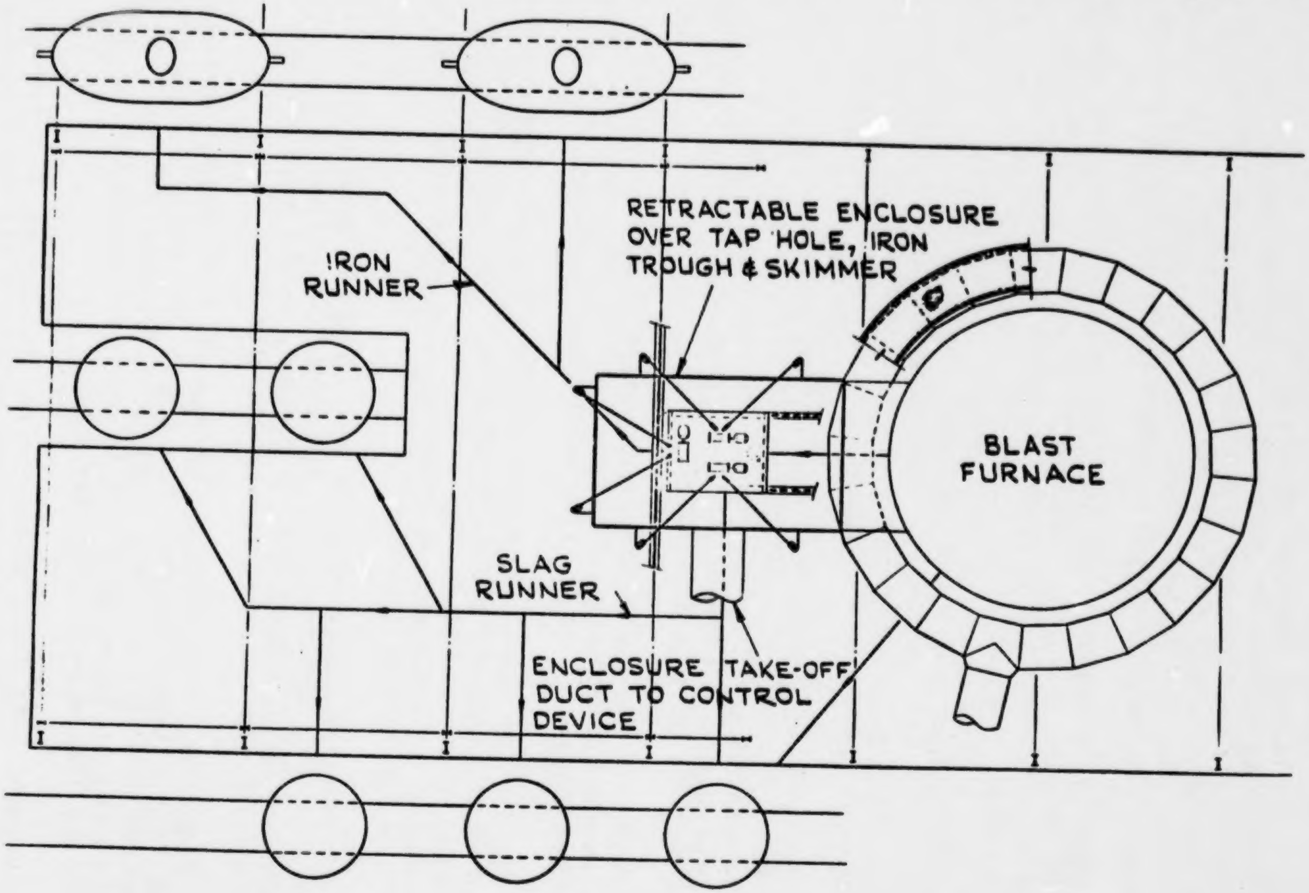

RETRACTABLE ENCLOSURE OVER TAP HOLE, IRON TROUGH & SKIMMER
IRON RUNNER
BLAST FURNACE
SLAG RUNNER
ENCLOSURE TAKE-OFF DUCT TO CONTROL DEVICE

Figure 7-2
FRONT ELEVATION SINGLE TAP HOLE FURNACE
PARTIAL EMISSION CONTROL CONCEPT

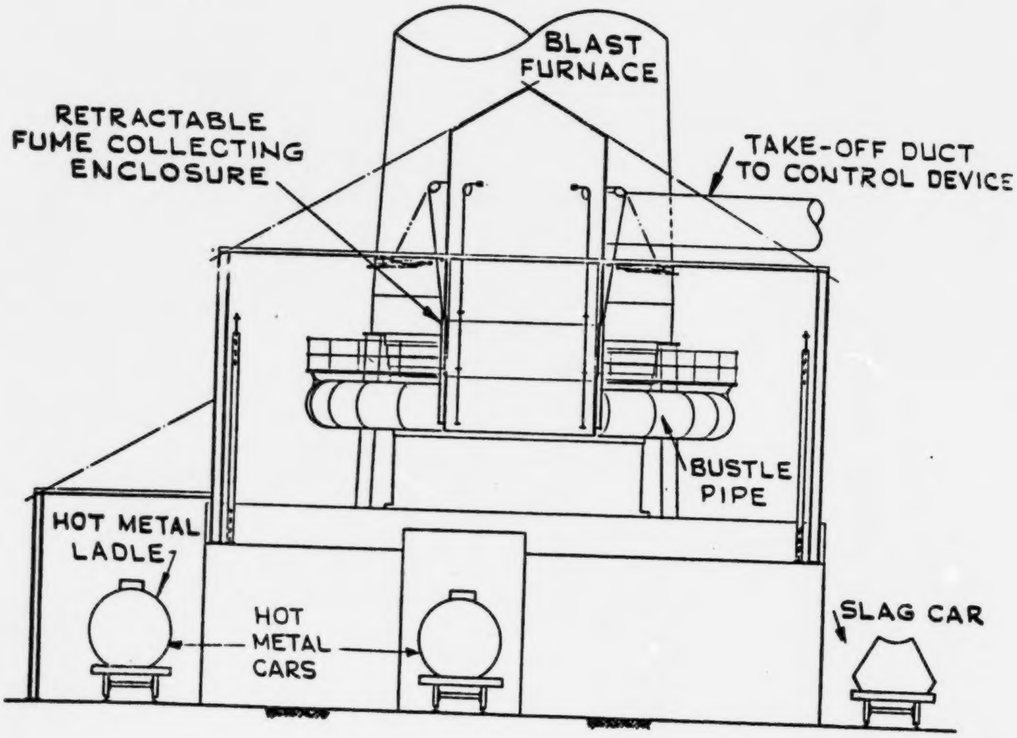

BLAST FURNACE
RETRACTABLE FUME COLLECTING ENCLOSURE
TAKE-OFF DUCT TO CONTROL DEVICE
BUSTLE PIPE
HOT METAL LADLE
HOT METAL CARS
SLAG CAR

Figure 7-3
SIDE ELEVATION VIEW SINGLE TAP HOLE FURNACE PARTIAL EMISSION CONTROL CONCEPT

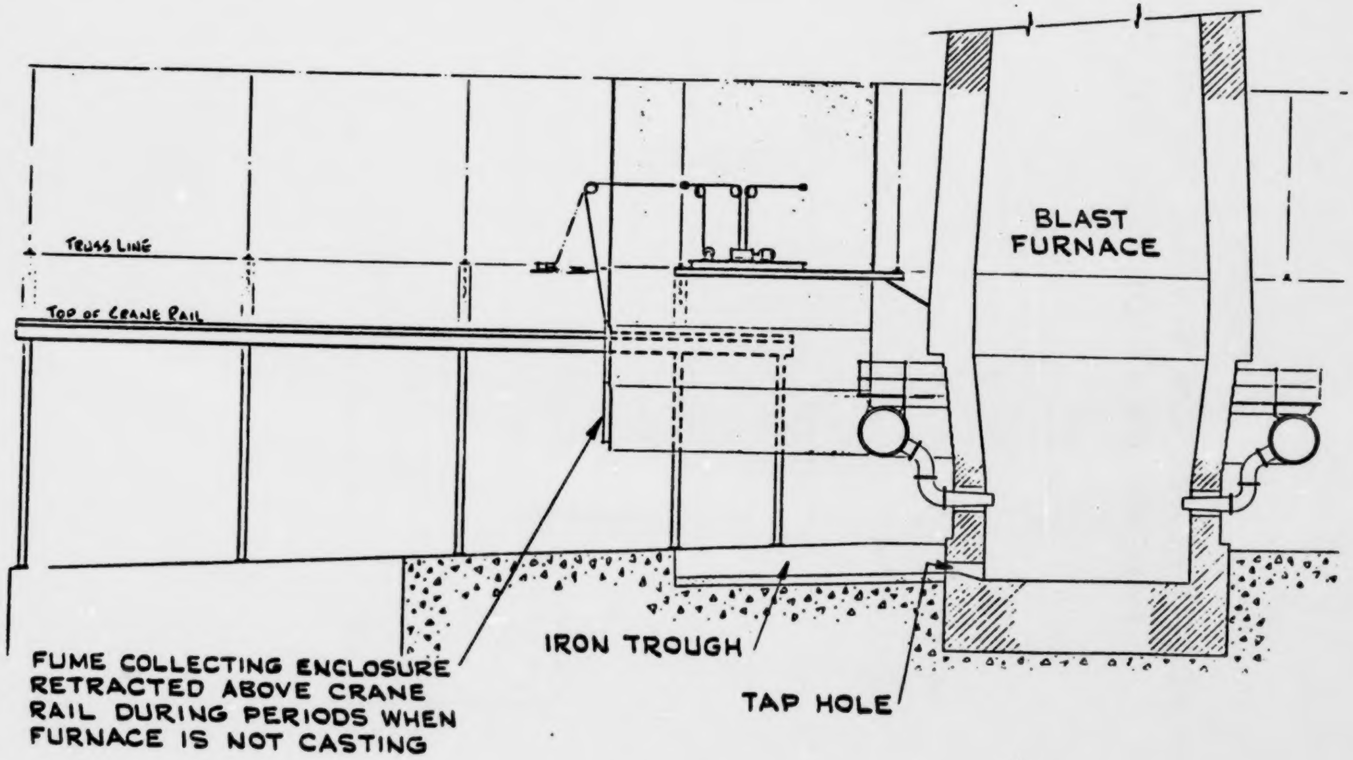

BLAST FURNACE
TRUSS LINE
TOP OF CRANE RAIL
FUME COLLECTING ENCLOSURE RETRACTED ABOVE CRANE RAIL DURING PERIODS WHEN FURNACE IS NOT CASTING
IRON TROUGH
TAP HOLE

Figure 7-4
TELESCOPING METAL PLATES
TOP PLATE HINGED

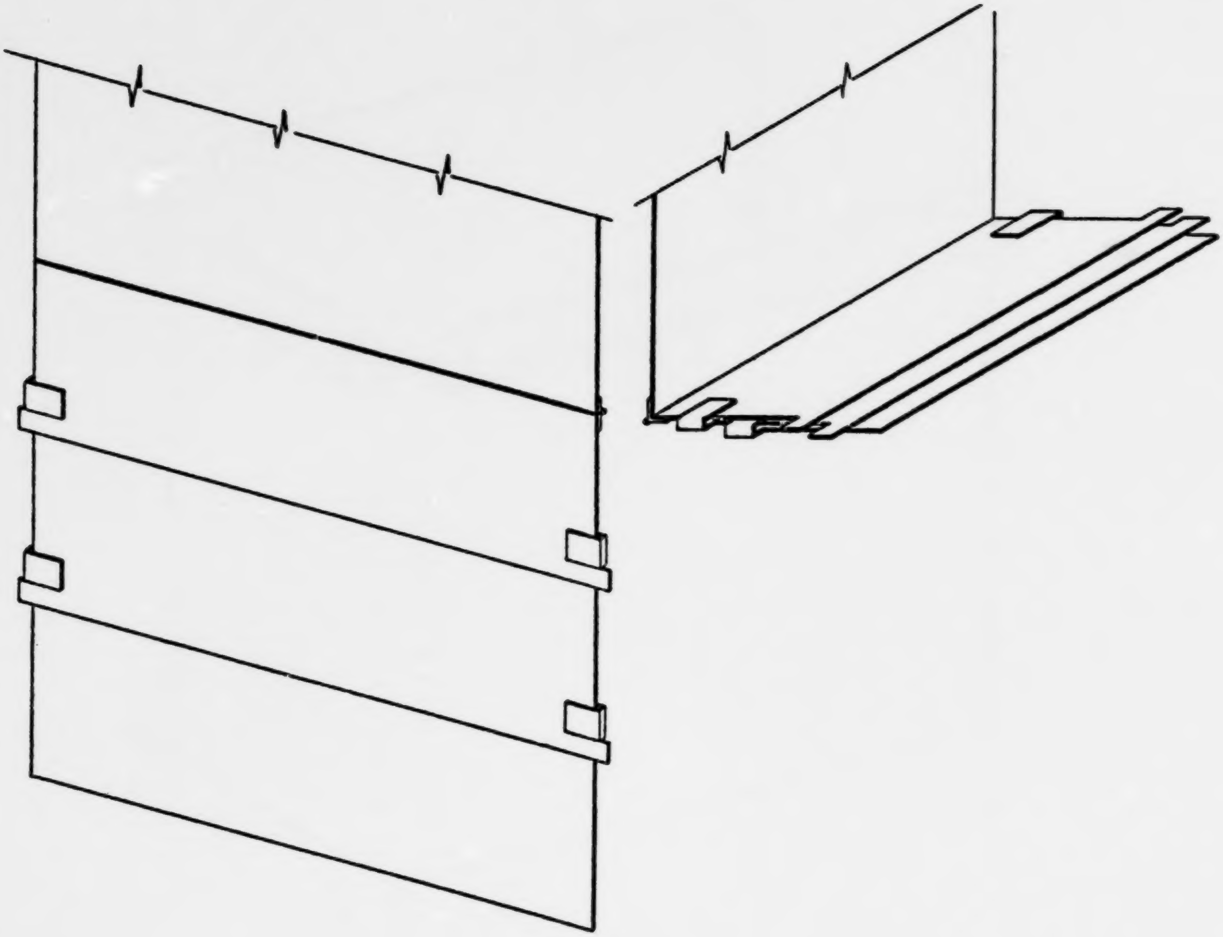


Figure 7-5
ROLL-UP CURTAIN LOCK-BOTTOM
WITH GUY WIRE AT REAR

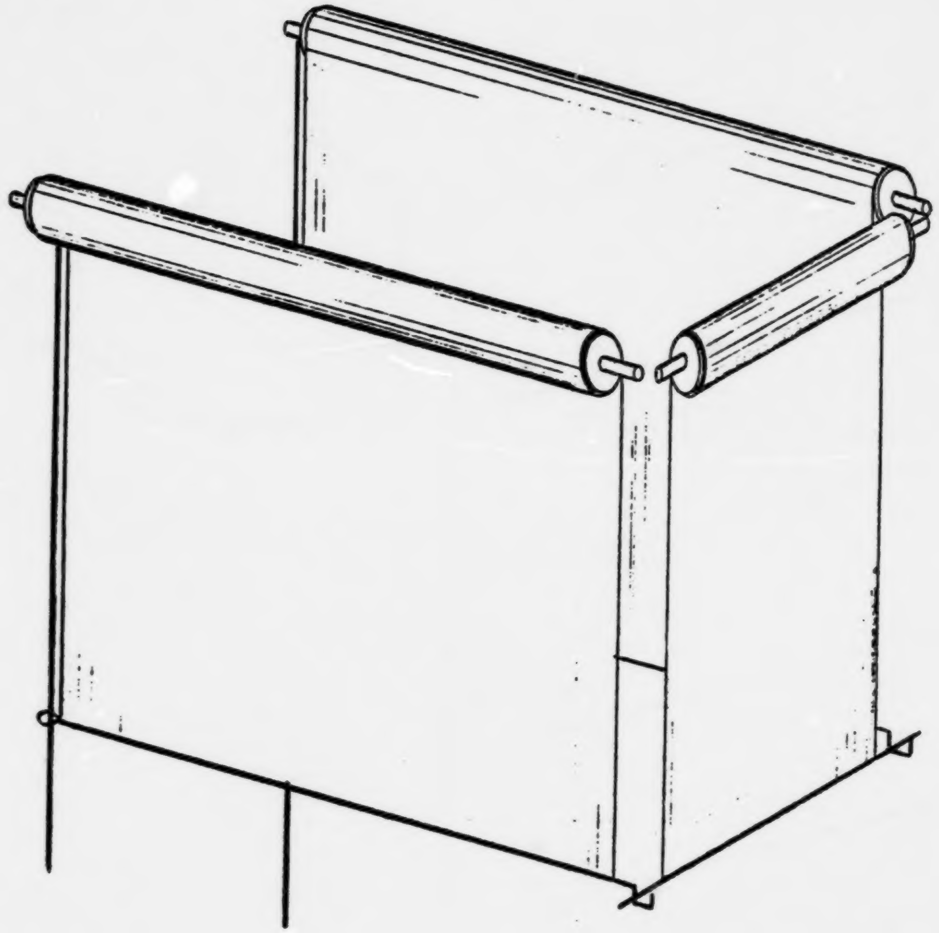


Figure 7-6

ROLL-UP CURTAIN FROM BOTTOM

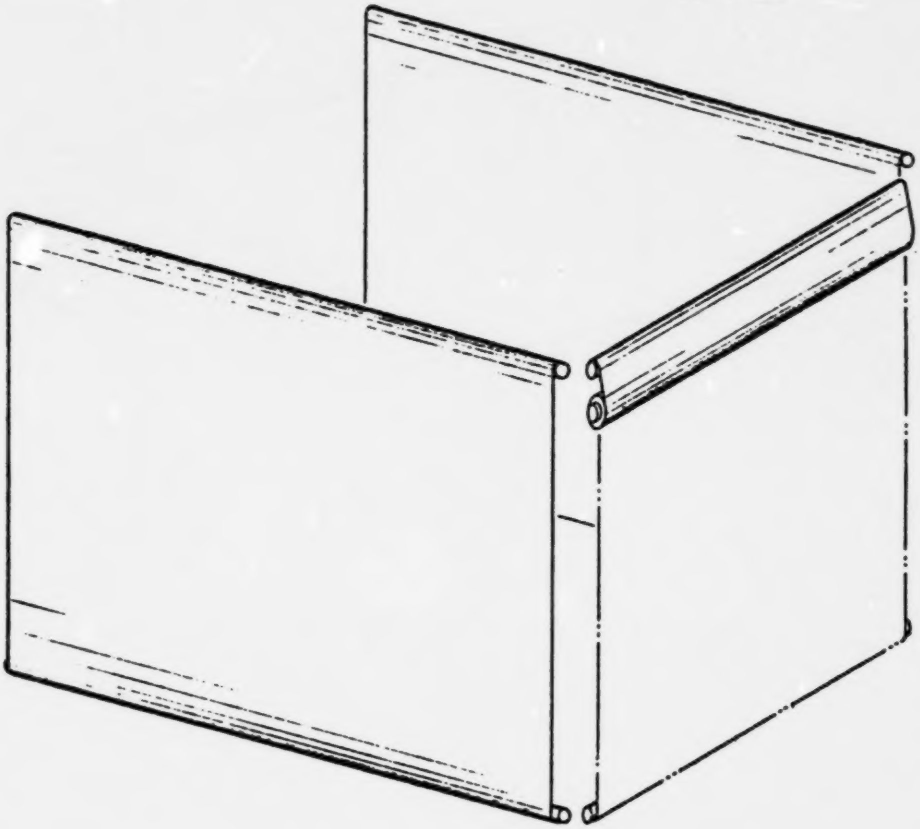


Figure 7-7
ROLL-UP INTO AREA BETWEEN CRANE AND TRUSSES

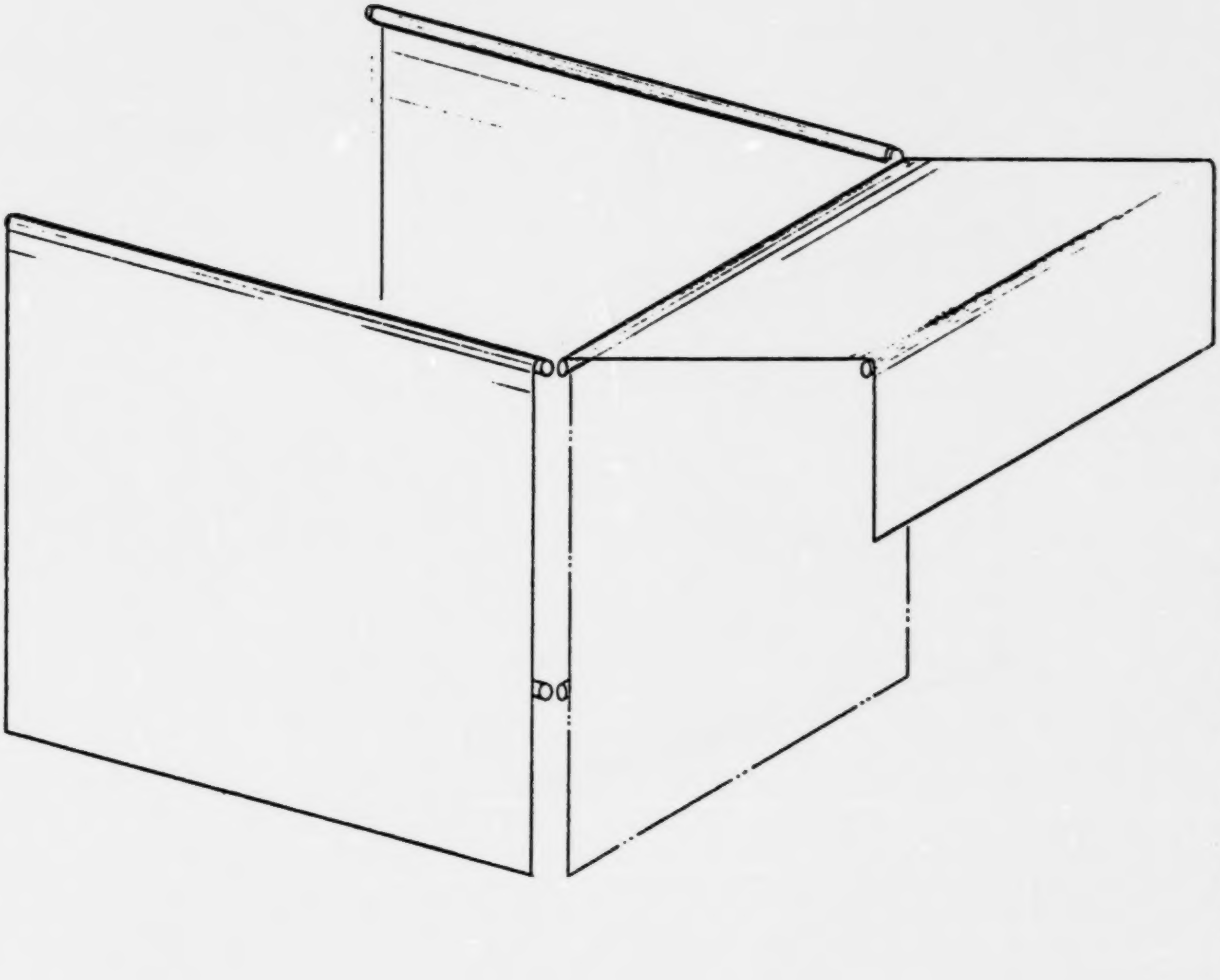


Figure 7-8
VENETIAN BLIND TYPE METAL SLATS

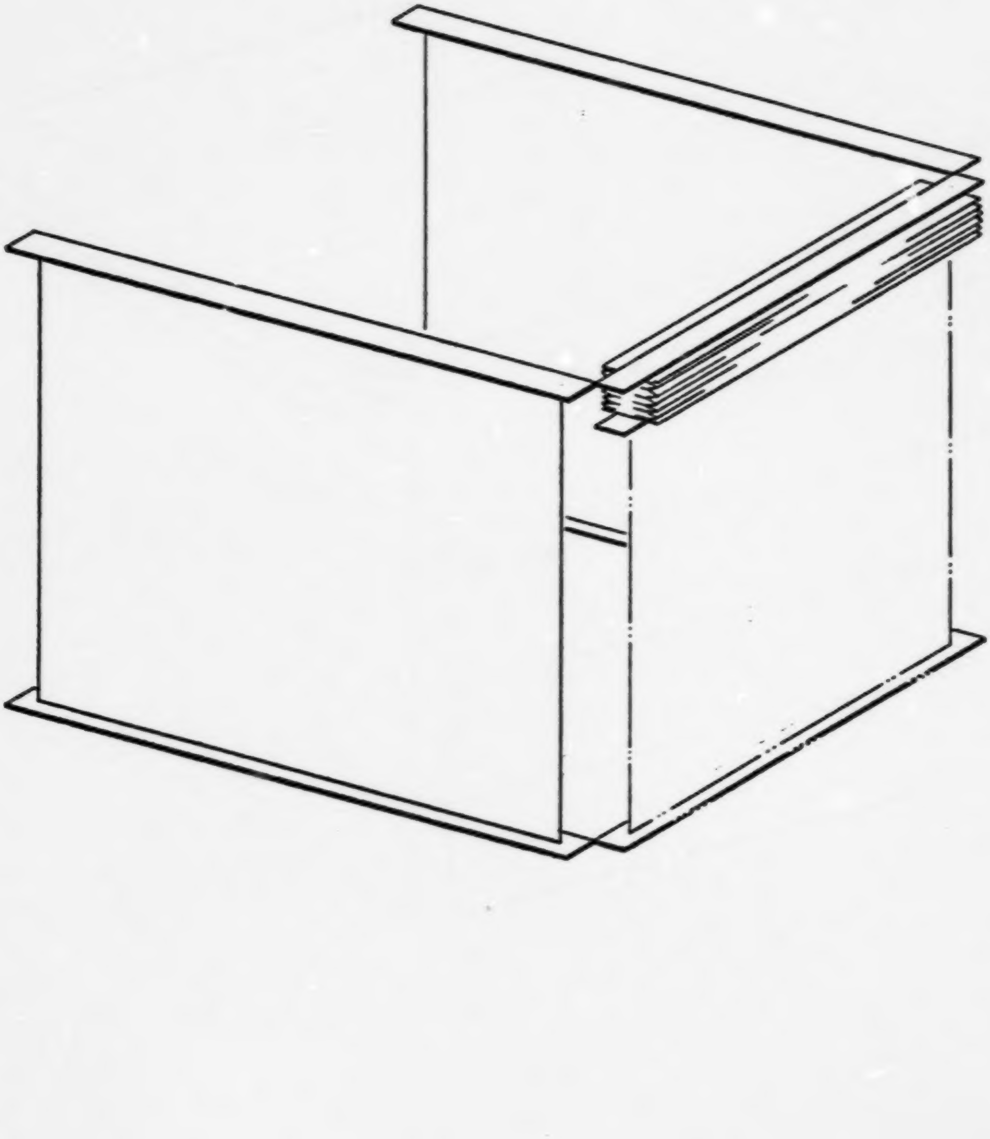


Figure 7-9
FOLD-UP METAL PLATES

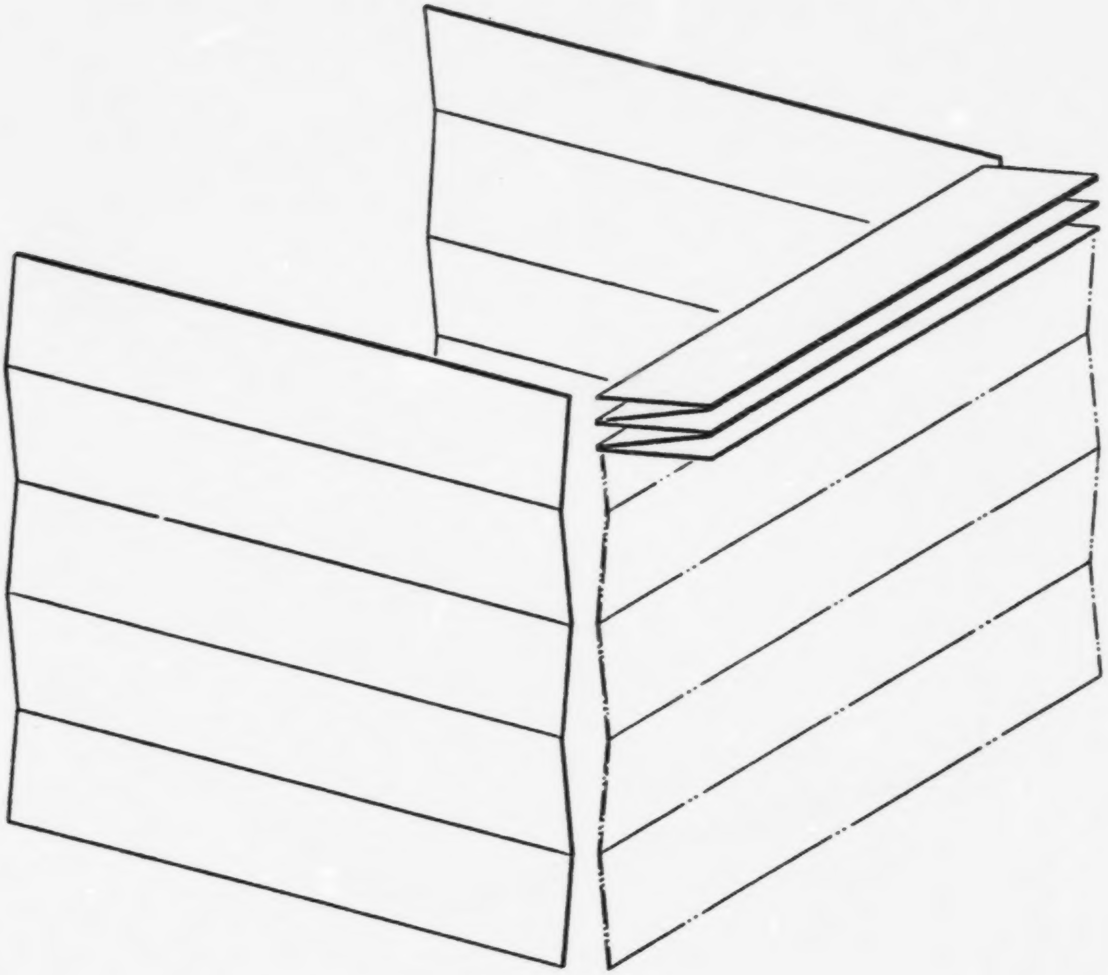


Figure 7-10
FOLD-UP METAL PLATES

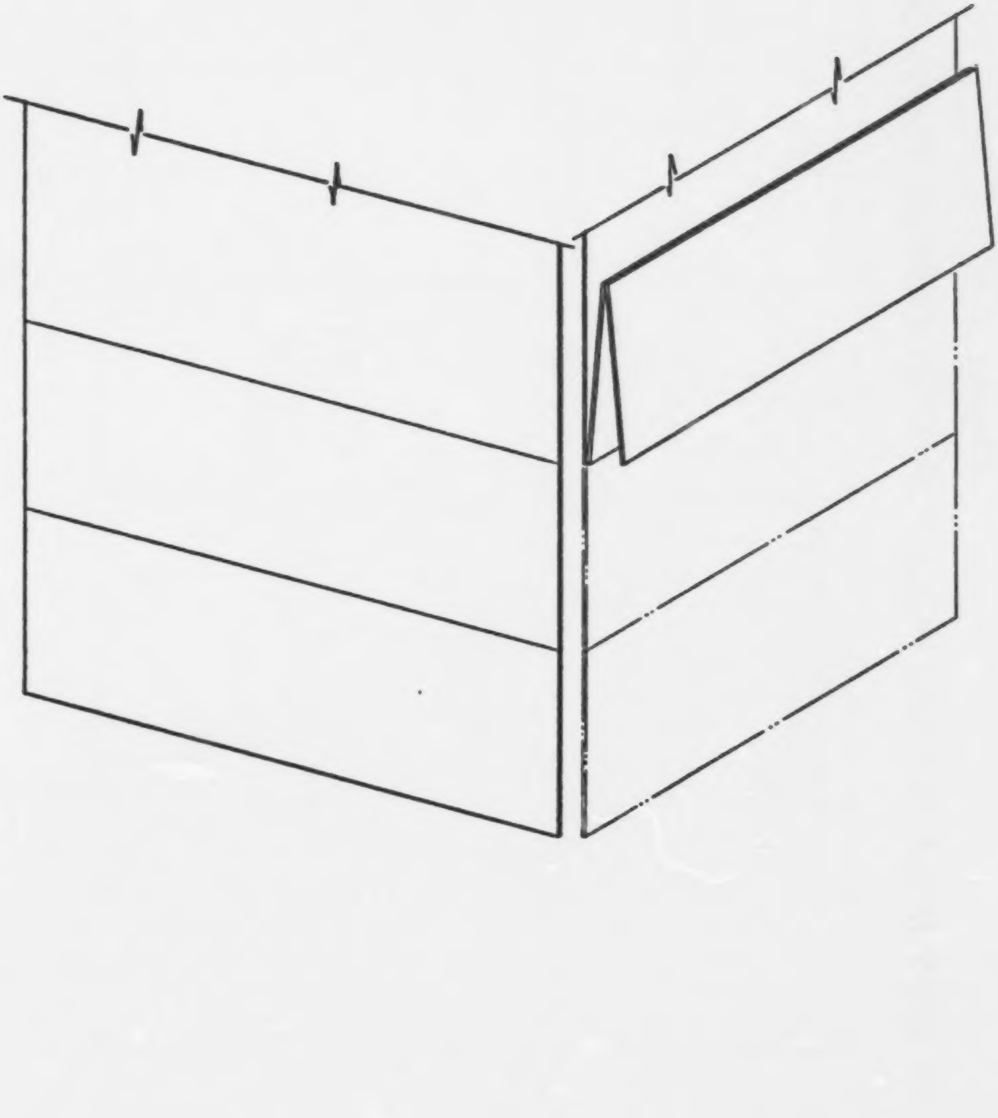


Figure 7-11

PLAN VIEW MULTIPLE TAP HOLE FURNACE PARTIAL EMISSION CONTROL CONCEPT

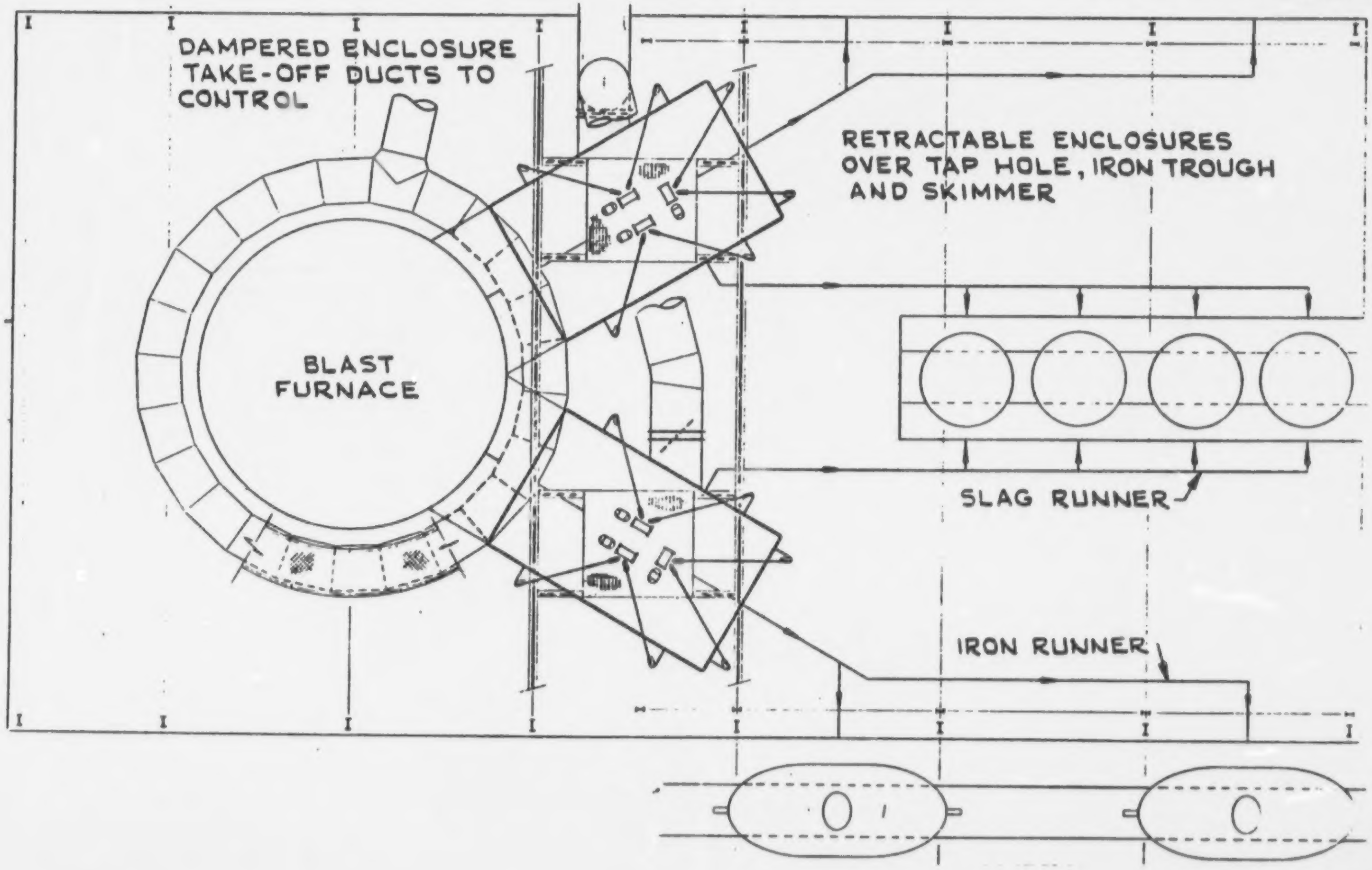

DAMPERED ENCLOSURE TAKE-OFF DUCTS TO CONTROL
RETRACTABLE ENCLOSURES OVER TAP HOLE, IRON TROUGH AND SKIMMER
BLAST FURNACE
SLAG RUNNER
IRON RUNNER

Figure 7-12
RETRACTABLE HOOD FOR PARTIAL CONTROL

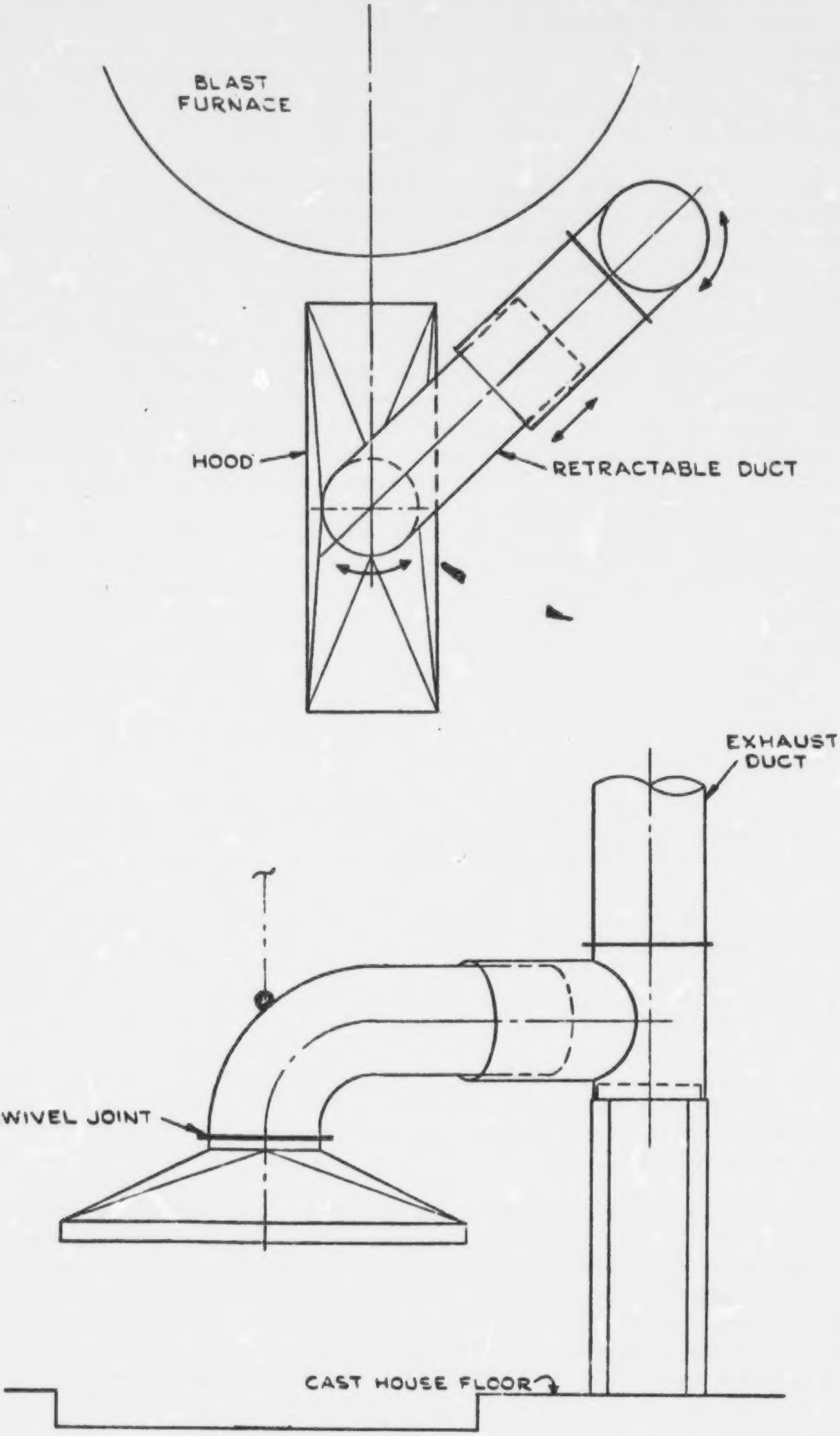

BLAST FURNACE
HOOD
RETRACTABLE DUCT
EXHAUST DUCT
SWIVEL JOINT
CAST HOUSE FLOOR

Figure 7-12 is a sketch of a swinging metal hood concept that is pivoted from a stanchion located out of the crane runway area. The hood swings and telescopes when not in use. The hood also telescopes in vertical travel to clear the mud gun and drill. Cables from winches located in the trusses would raise and lower the hood and swing it away when not in use.

Calculations were made to estimate temperatures and volumes of off-gases from a curtain enclosure of selected size. (See Appendix B pages B-2 through B-6). These calculations indicate that a volume of exhaust air of 90.8 m^3/sec (192,000 ACFM) with fume will exit the enclosure at a temperature of 79°C (174°F). This volume is based on a face velocity of 1.27 meters per second (250 FPM) through the open areas between the enclosure and the cast house floor (See page B-6 of Appendix B). An in-draft or face velocity of 1.27 meters per second should be sufficient to prevent fume which is generated in the tap hole and trough zone from escaping the enclosure if there are minimal cross-drafts within the cast house. If necessary, the face velocity can be increased by either altering the design or configuration to reduce the open areas of the enclosure while maintaining the exhaust volume or by increasing the exhaust volume. Control of emissions at the tap hole and iron trough should capture a high percentage of the cast house emissions and is a potential solution to the cast house air pollution problem. This approach would augment the process revision alternative discussed in the first alternative and which is the logical first step for consideration. The curtain enclosure would exhaust to a baghouse (See Figure 7-13).

Figure 7-14 illustrates the flow of emissions from a typical blast furnace employing partial control by the curtain system, and Table 7-1 tabulates 1976 order-of-magnitude (>±30%) costs.

Because the Japanese have used retractable curtains as part of cast house ventilation design, the possibility exists that a practical design for a partial control hood can be developed. This could only be verified from actual installations or selective demonstration systems.

This type of installation may satisfy most regulations for process weight emissions. However, it is doubtful if any control system other than total control would meet a requirement for no-visible emissions.

Any additional equipment or trough systems applied to the cast house would of necessity increase the number of maintenance personnel and the overall operating problem. Areas within the cast house would have to be reserved to work on the equipment involved, and cranes and moving equipment would be needed to install and move hooding. Normal maintenance of the control device would have to be provided, such as replacement of fabric

Figure 7-13

COLLECTING SYSTEM FOR PARTIAL EVACUATION 94.4 M^3/Sec.

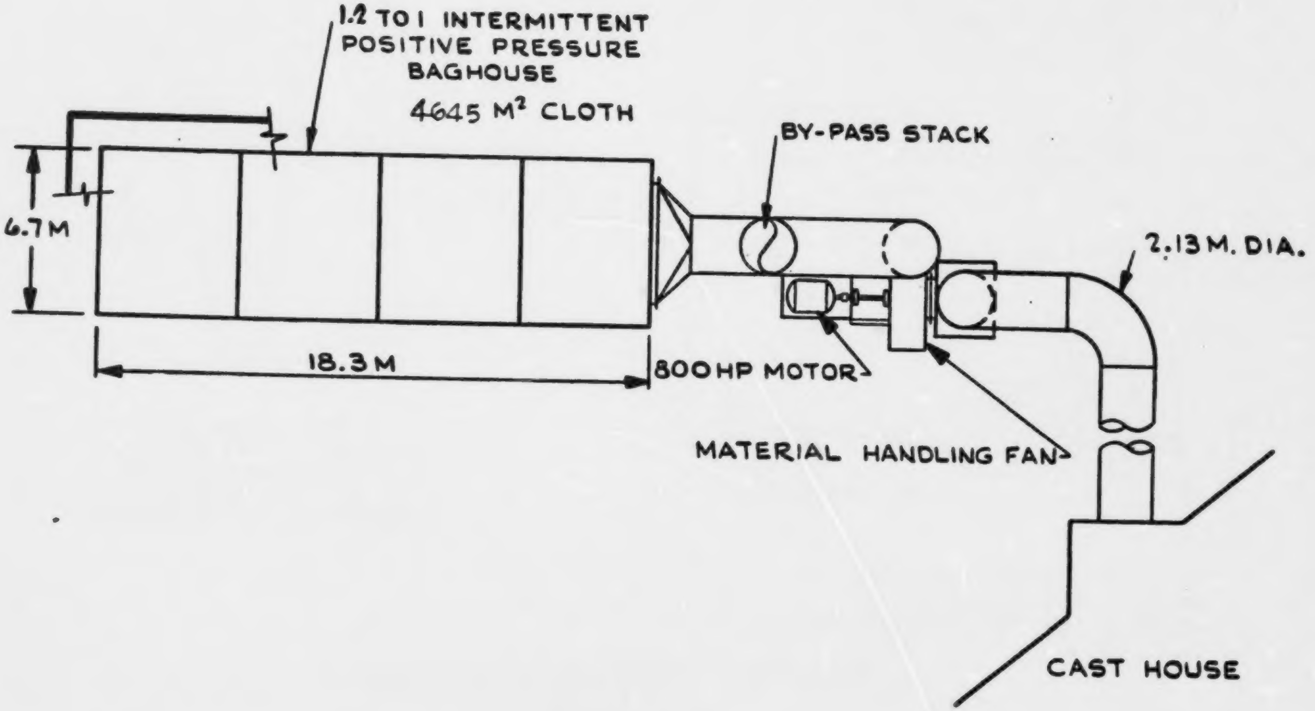
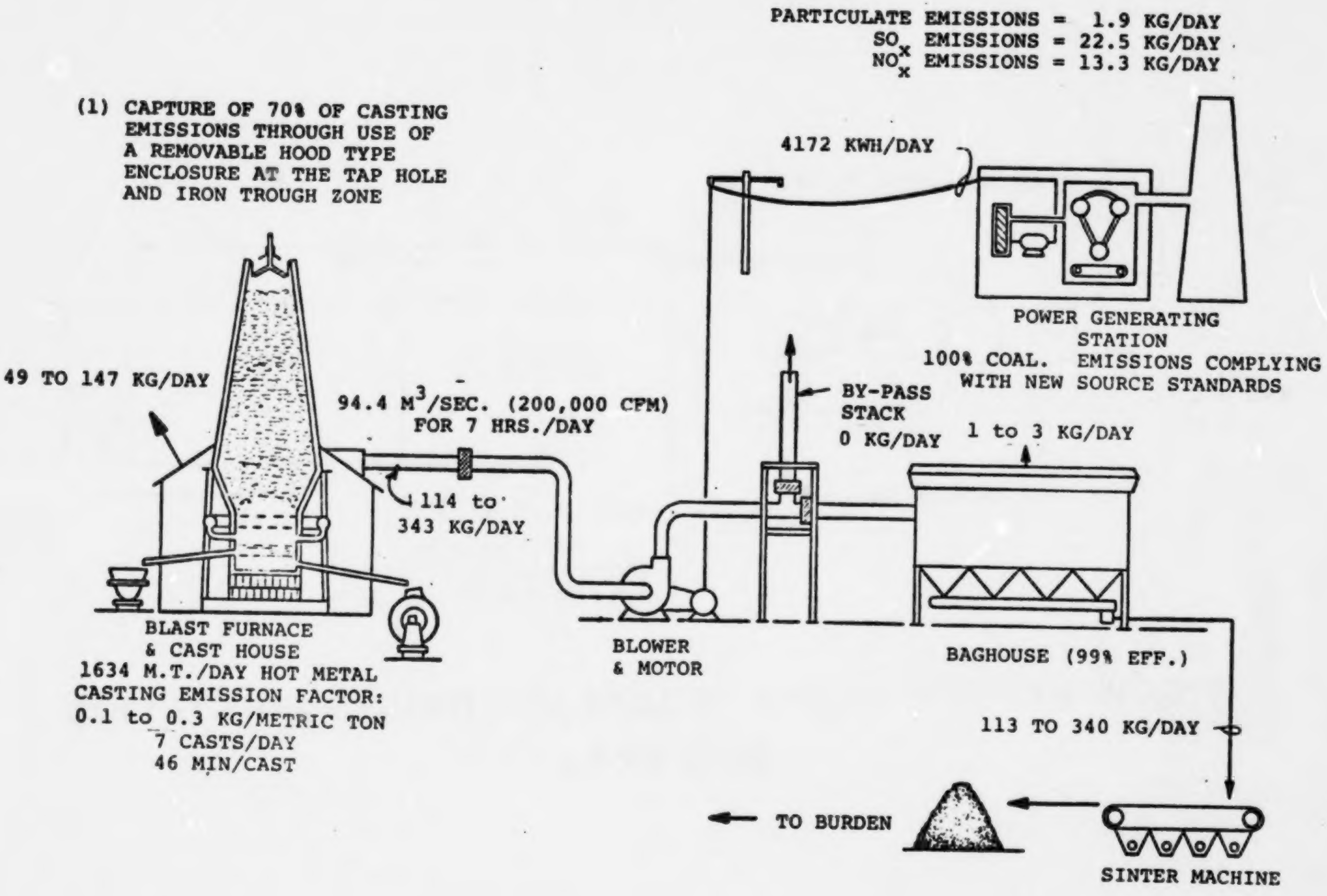

1.2 TO 1 INTERMITTENT
POSITIVE PRESSURE
BAGHOUSE
4645 M^2 CLOTH
BY-PASS STACK
6.7 M
2.13 M. DIA.
18.3 M
800 HP MOTOR
MATERIAL HANDLING FAN
CAST HOUSE

Figure 7-14
PARTIAL CONTROL VALUES(1)



PARTICULATE EMISSIONS = 1.9 KG/DAY
SO_x EMISSIONS = 22.5 KG/DAY
NO_x EMISSIONS = 13.3 KG/DAY
4172 KWH/DAY
POWER GENERATING STATION
100% COAL. EMISSIONS COMPLYING WITH NEW SOURCE STANDARDS
49 TO 147 KG/DAY
94.4 M^3/SEC. (200,000 CFM) FOR 7 HRS./DAY
114 to 343 KG/DAY
BY-PASS STACK
0 KG/DAY
1 to 3 KG/DAY
BLAST FURNACE & CAST HOUSE
1634 M.T./DAY HOT METAL
CASTING EMISSION FACTOR:
0.1 to 0.3 KG/METRIC TON
7 CASTS/DAY
46 MIN/CAST
BLOWER & MOTOR
BAGHOUSE (99% EFF.)
113 TO 340 KG/DAY
TO BURDEN
SINTER MACHINE

(1) CAPTURE OF 70% OF CASTING EMISSIONS THROUGH USE OF A REMOVABLE HOOD TYPE ENCLOSURE AT THE TAP HOLE AND IRON TROUGH ZONE

TABLE NO. 7-1
COST BREAKDOWN PER ANNUM OF 94.4 M3/SEC. (200,000 CFM) PARTIAL CONTROL CURTAIN SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	85,203.	121,900.	0.	97,520.	165,599.	55,274.	536,096.	.9259	496,385.
2	11,236.	90,315.	129,214.	0.	103,371.	161,178.	59,695.	555,009.	.8573	475,831.
3	11,910.	95,734.	136,967.	0.	109,573.	156,402.	64,471.	575,057.	.7938	456,499.
4	12,625.	101,478.	145,185.	0.	116,148.	151,245.	69,628.	596,309.	.7350	438,305.
5	13,382.	107,567.	153,896.	0.	123,117.	145,674.	75,199.	618,835.	.6806	421,169.
6	14,185.	114,021.	163,130.	0.	130,504.	139,659.	81,214.	642,712.	.6302	405,018.
7	15,036.	120,862.	172,917.	0.	138,334.	133,162.	87,712.	668,023.	.5835	389,785.
8	15,938.	128,113.	183,292.	0.	146,634.	126,144.	94,730.	694,852.	.5403	375,407.
9	16,895.	135,800.	194,290.	0.	155,432.	118,567.	102,307.	723,290.	.5002	361,825.
10	17,908.	143,948.	205,947.	42,980.	164,758.	110,381.	110,492.	796,416.	.4632	368,895.
11	18,983.	152,585.	218,304.	0.	174,643.	101,542.	119,331.	785,389.	.4289	336,840.
12	20,122.	161,740.	231,402.	0.	185,122.	91,995.	128,878.	819,260.	.3971	325,340.
13	21,329.	171,445.	245,287.	0.	196,229.	81,686.	139,187.	855,163.	.3677	314,442.
14	22,609.	181,731.	260,004.	0.	208,003.	70,550.	150,323.	893,220.	.3405	304,107.
15	23,966.	192,635.	275,604.	0.	220,483.	58,525.	162,348.	933,561.	.3152	294,298.
16	25,493.	204,193.	292,140.	0.	233,712.	45,536.	175,337.	976,322.	.2919	284,980.
17	26,928.	216,445.	309,669.	0.	247,735.	31,511.	189,362.	1,021,649.	.2703	276,121.
18	28,543.	229,432.	328,249.	0.	262,599.	16,360.	204,513.	1,069,696.	.2502	267,691.
							$2,070,000.			$6,592,930.
										$230,000.
										$6,822,930.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $24,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $2,300,000.
AMOUNT FINANCED = $2,070,000.

and removal of upper dust in a baghouse. Maintenance factors are known to be high on fabric filters and special personnel must be trained to handle the problems involved. If air moving equipment, for example, should be taken off stream for maintenance on a totally-evacuated, closed cast house, a back-up ventilation system would be required to maintain an acceptable working environment. With this condition, natural ventilation could be achieved by opening roof monitors and additional side wall air inlets. There is a relationship between maintenance and productivity; and the additional equipment which would be required to effect a pollution control solution would add to the maintenance required to ensure high productivity. Many problems which are now encountered in casting hot metal such as trough explosions and wild casts must be considered in the design of any system to minimize system damage and added clean-up efforts.

PARTIAL CONTROL OF CAST HOUSE EMISSIONS INCLUDING PROCESS CHANGES

The partial control system in this alternative is the same as the one in the previous alternative. A substantial quantity of fumes from the runners may be decreased by modifying physical dimensions and by using alternative materials in the linings. The emissions from the hot metal are largely a function of temperature and surface area. Both of these variables could be studied to achieve diminished emissions. By moving the spouts closer to the dam a reduction in the length of the runners will be achieved reducing hot metal exposure and cooling and thus reducing emissions. However, to do so would entail extensive remodelling of the cast house as well as relocating the hot metal railroad tracks. The practicality of such alterations is suspected to be very limited.

Production and maintenance procedures to minimize problems can only be established through tests at an actual operating installation.

Based upon the first year total annual cost for a partial control system, as presented in Table 7-1, and a blast furnace that produces approximately 1500 tonnes per day (536,000 tonnes per year), the iron pool partial control installation would add approximately $1.00 per tonne to the cost of the production of hot metal. The AISI ad hoc committee estimates that the 1976 cost of production of hot metal is $120 per tonne.

TOTAL EMISSION CONTROL BY CAST HOUSE EVACUATION WITHOUT CONSIDERING PROCESS CHANGES

Total evacuation of the cast house could be achieved satisfactorily with a ventilation rate of 60 or more air changes per hour. This could require air volumes up to 28,300 cubic meters per minute (1,000,000 CFM) depending upon cast house volume. If the cast house volume exceeds 28,300 cubic meters (1,000,000 cubic feet), properly designed and installed baffles could segment the cast house volume and, by suitable programming of ventilation, permit essentially total evacuation with 28,300 cubic meters per minute (1,000,000 CFM). The cast house would be sufficiently closed to maintain an inlet velocity which would prevent upsets by cross-drafts. The ventilation rate could be cut back as much as 50% after casting is completed and the tap hole is closed. Evacuation rates vs. inlet velocities through open side areas of the cast house are shown on Figure 7-15. Power house emissions based on evacuation rates are shown on Figures 7-16 and 7-17 and 7-18.

Cast houses could be designed with adjustable louvers in the side sheets or side partitions which could be opened and closed between casts. Ventilation control could be synchronized with the opening and closing of side sheets, greatly reducing the amount of air necessary to ventilate the cast house between casts and during other non-operating phases. The primary advantage of total evacuation is that there are no structures or equipment in close proximity to the iron making operation. It does require closing cast house wall, floor and roof openings in order to control air flow, which could possibly cause atmospheric problems in the cast house.

The total evacuation principle of pollution control would have the least effect on productivity of the blast furnace. In the case of individual or localized hooding, problems could arise which would curtail productivity to some extent. For example, maintenance ,scheduled or otherwise, on a hooded runner or a breakdown in the operation of a retractable enclosure or curtain-type hood could delay casting operations and reduce production. It is the opinion of some blast furnace operators that no maintenance work could be conducted on a producing furnace. The unions and operating personnel could require a shutdown in order to perform maintenance functions on a hood or cover on a single tap hole furnace. Therefore, there is the possibility that anything other than total control of fumes from the cast house through the use of total evacuation could create a decrease in production.

The 1976 order-of-magnitude (>±30%) cost to install a total evacuation system, including baghouse, fan, and ductwork with dampers, is shown in Figures 7-19 and 7-20. For example, at a rate of 330m³/sec. (700,000 CFM) the system would cost about $5.00 per tonne of hot metal. Total costs for systems from 94 m³/sec. (200,000 CFM) to 472 m³/sec. (1,000,000 CFM) are tabulated on Tables 7-2 thru 7-10. Site specific costs could result in significant deviations from the approximations. The capital costs presented in these figures and tables are approximately 25% less than the costs presented in the Arthur D.

Figure 7-15

CAST HOUSE SIDE WALL INLET VELOCITIES DUE TO TOTAL EVACUATION VENTILATION RATES

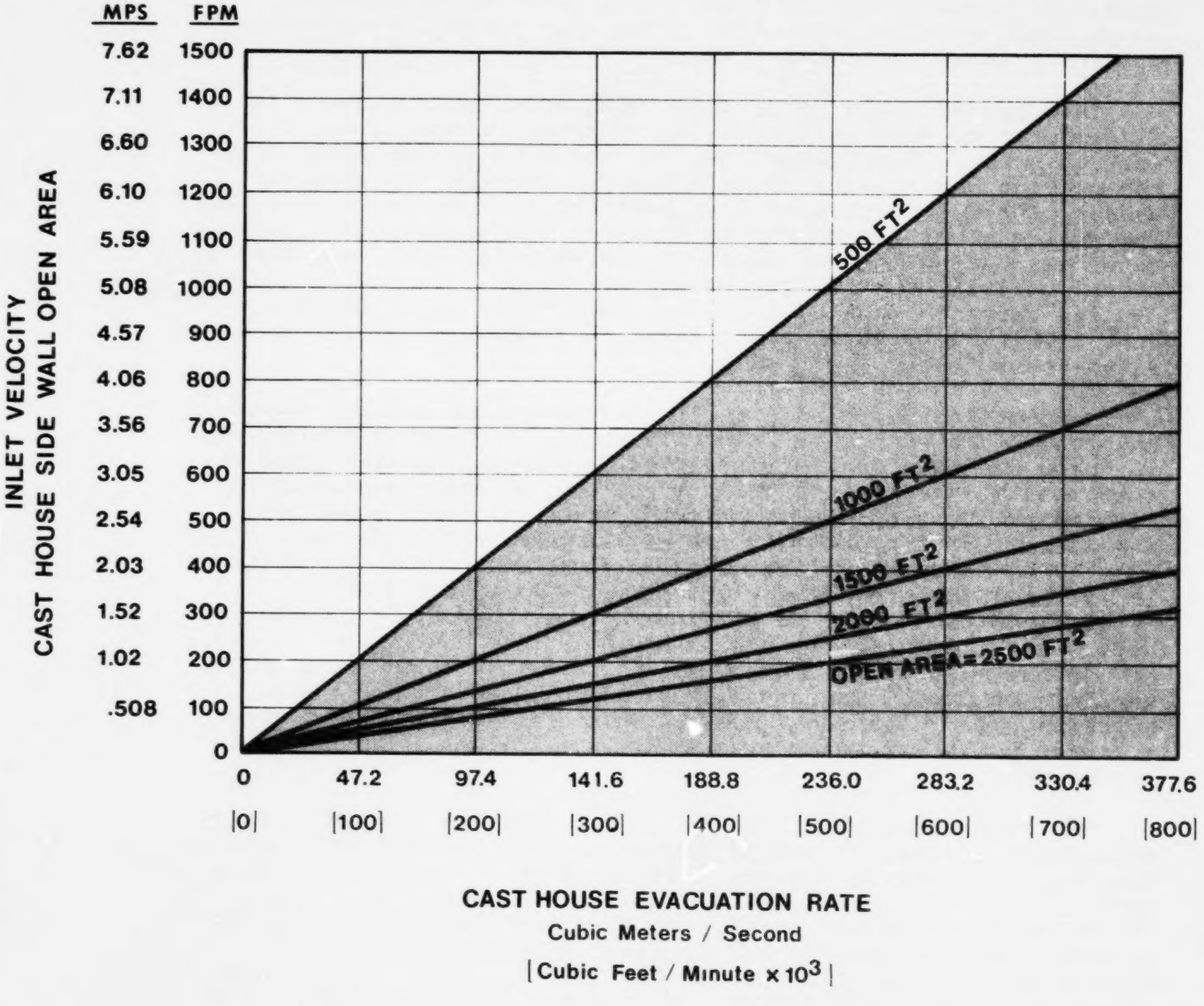


Figure 7-16

HORSEPOWER REQUIREMENTS FOR CAST HOUSE TOTAL EVACUATION

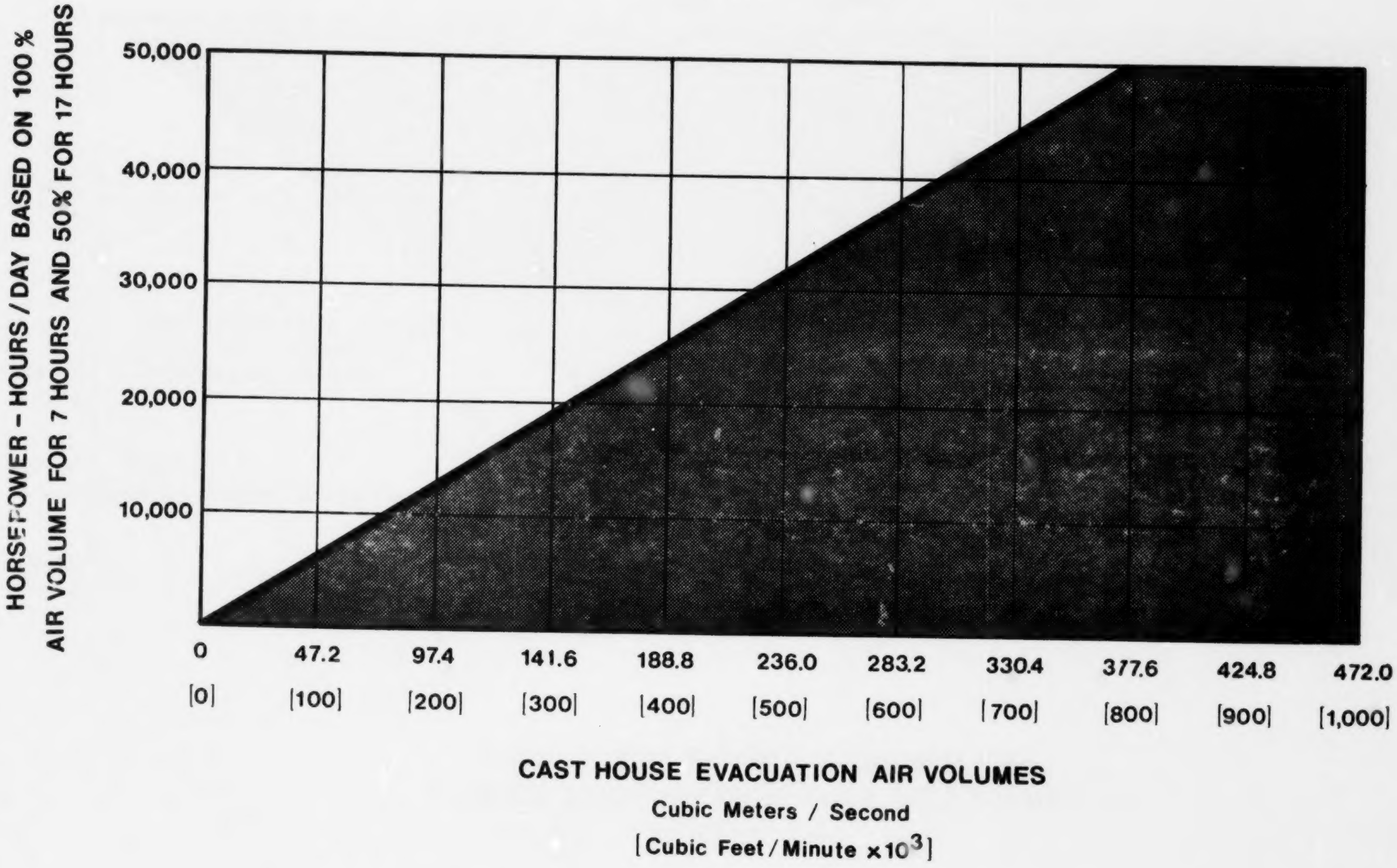


Figure 7-17
POWER PLANT EMISSIONS RESULTING
FROM CAST HOUSE EVACUATION

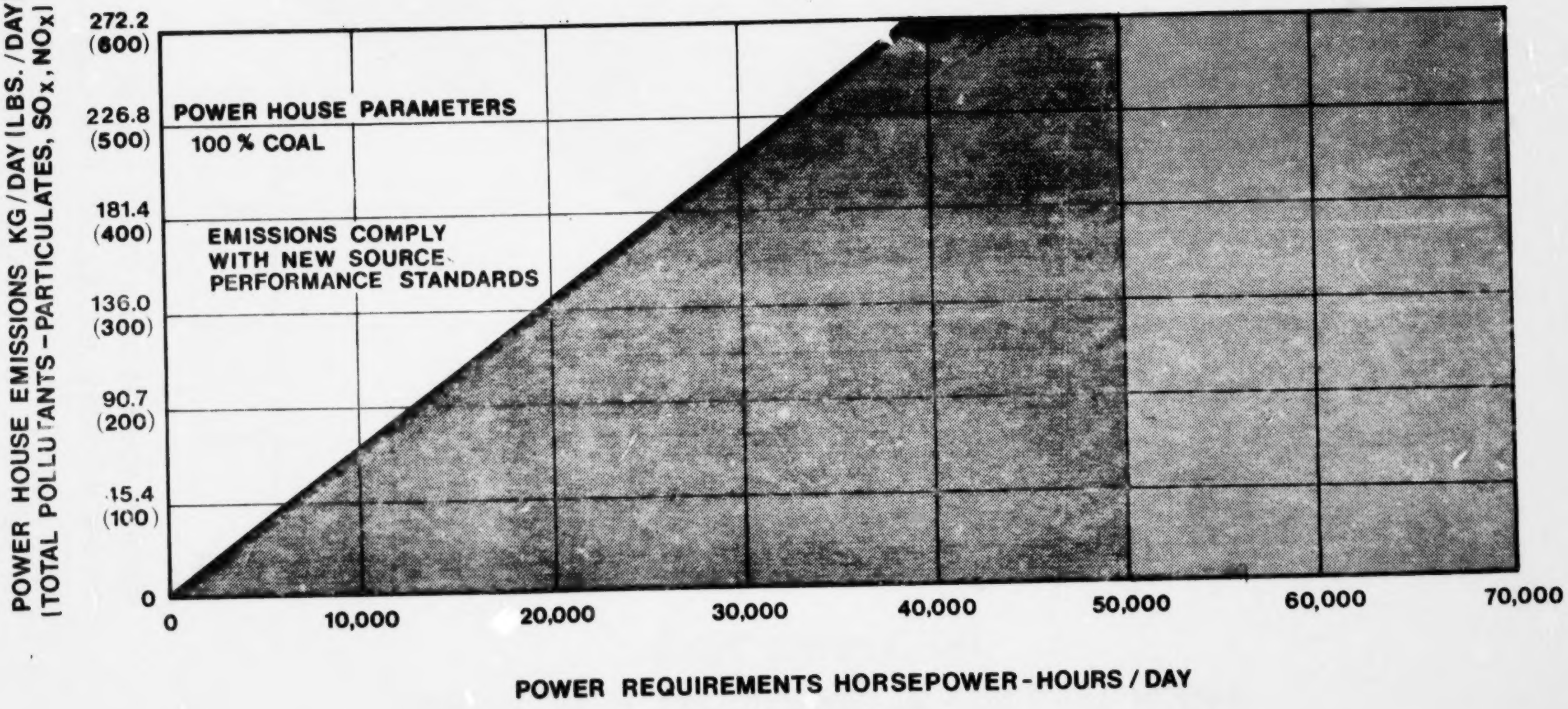
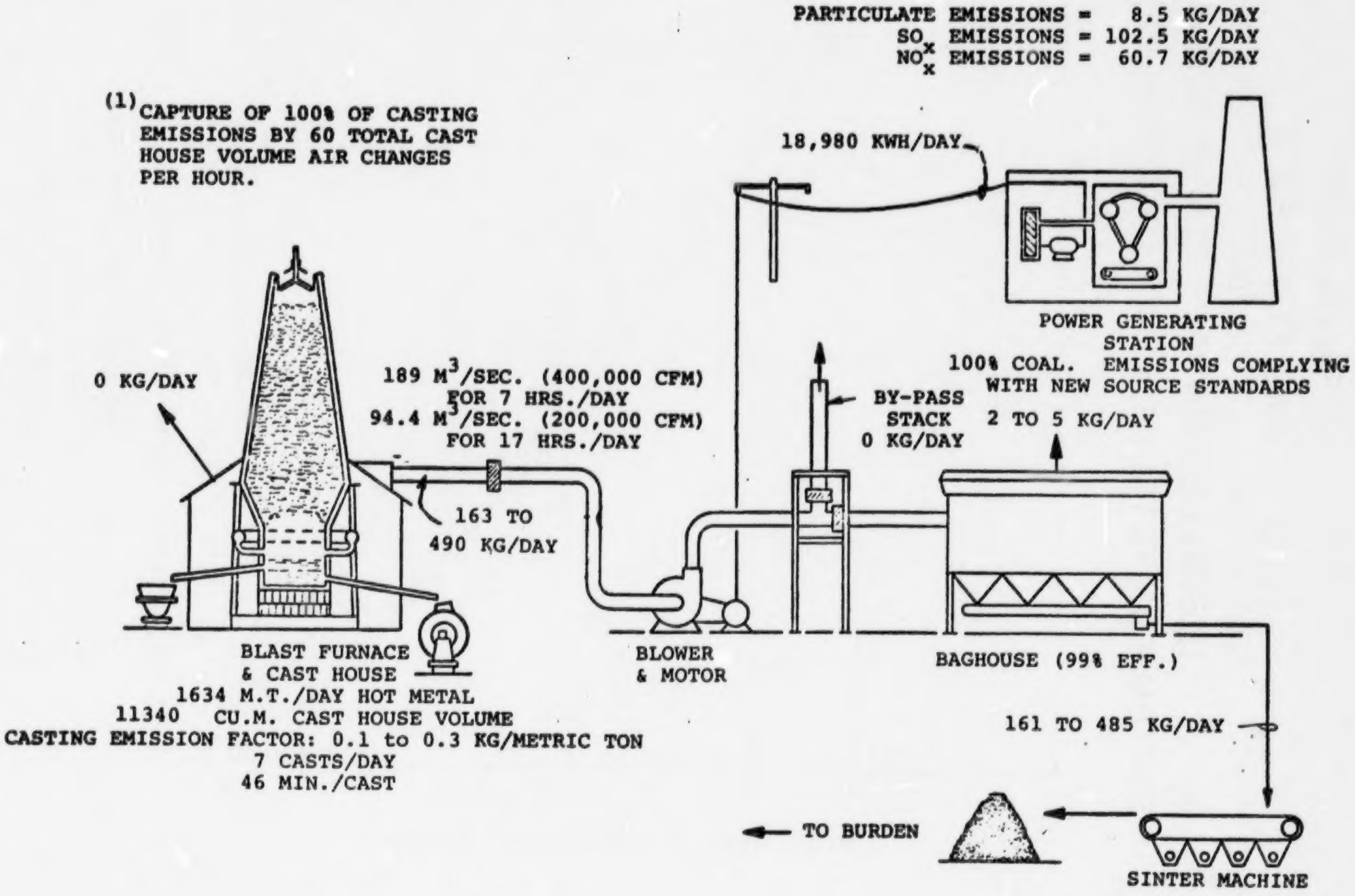


Figure 7-18
TOTAL EVACUATION VALUES(1)


PARTICULATE EMISSIONS = 8.5 KG/DAY
SO_x EMISSIONS = 102.5 KG/DAY
NO_x EMISSIONS = 60.7 KG/DAY
18,980 KWH/DAY
POWER GENERATING STATION
100% COAL. EMISSIONS COMPLYING WITH NEW SOURCE STANDARDS
0 KG/DAY
189 M^3/SEC. (400,000 CFM) FOR 7 HRS./DAY
94.4 M^3/SEC. (200,000 CFM) FOR 17 HRS./DAY
BY-PASS STACK
0 KG/DAY
2 TO 5 KG/DAY
163 TO 490 KG/DAY
BLAST FURNACE & CAST HOUSE
1634 M.T./DAY HOT METAL
11340 CU.M. CAST HOUSE VOLUME
CASTING EMISSION FACTOR: 0.1 to 0.3 KG/METRIC TON
7 CASTS/DAY
46 MIN./CAST
BLOWER & MOTOR
BAGHOUSE (99% EFF.)
161 TO 485 KG/DAY
TO BURDEN
SINTER MACHINE

(1) CAPTURE OF 100% OF CASTING EMISSIONS BY 60 TOTAL CAST HOUSE VOLUME AIR CHANGES PER HOUR.

Figure 7-19

GAS FLOW RATE
vs.
INSTALLED COST OF CLOTH COLLECTOR SYSTEM FOR TOTAL CONTROL OR COMPLETE EVACUATION

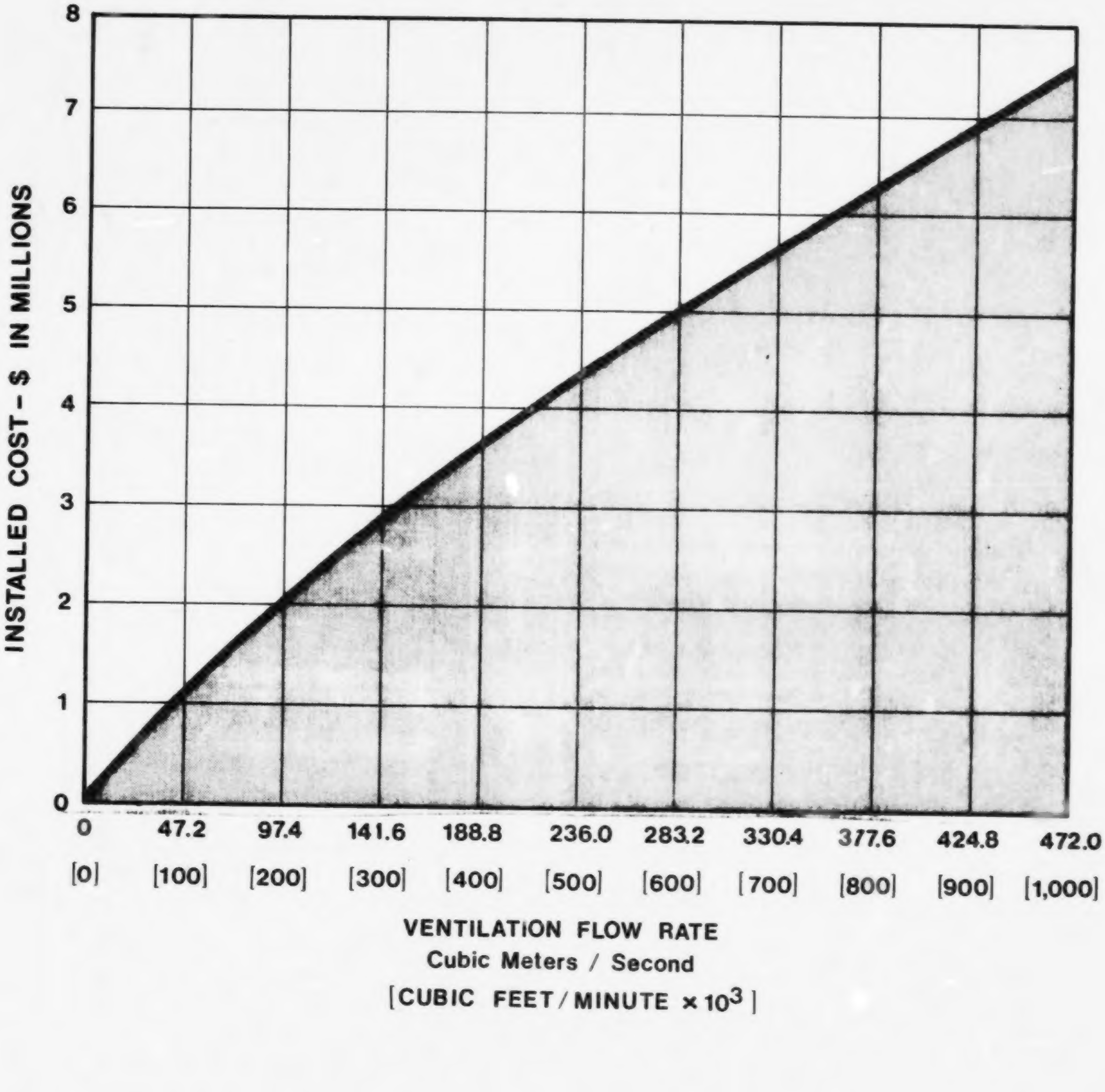


Figure 7-20

INSTALLED UNIT COST FOR CLOTH COLLECTOR SYSTEM FOR TOTAL CONTROL OR COMPLETE EVACUATION

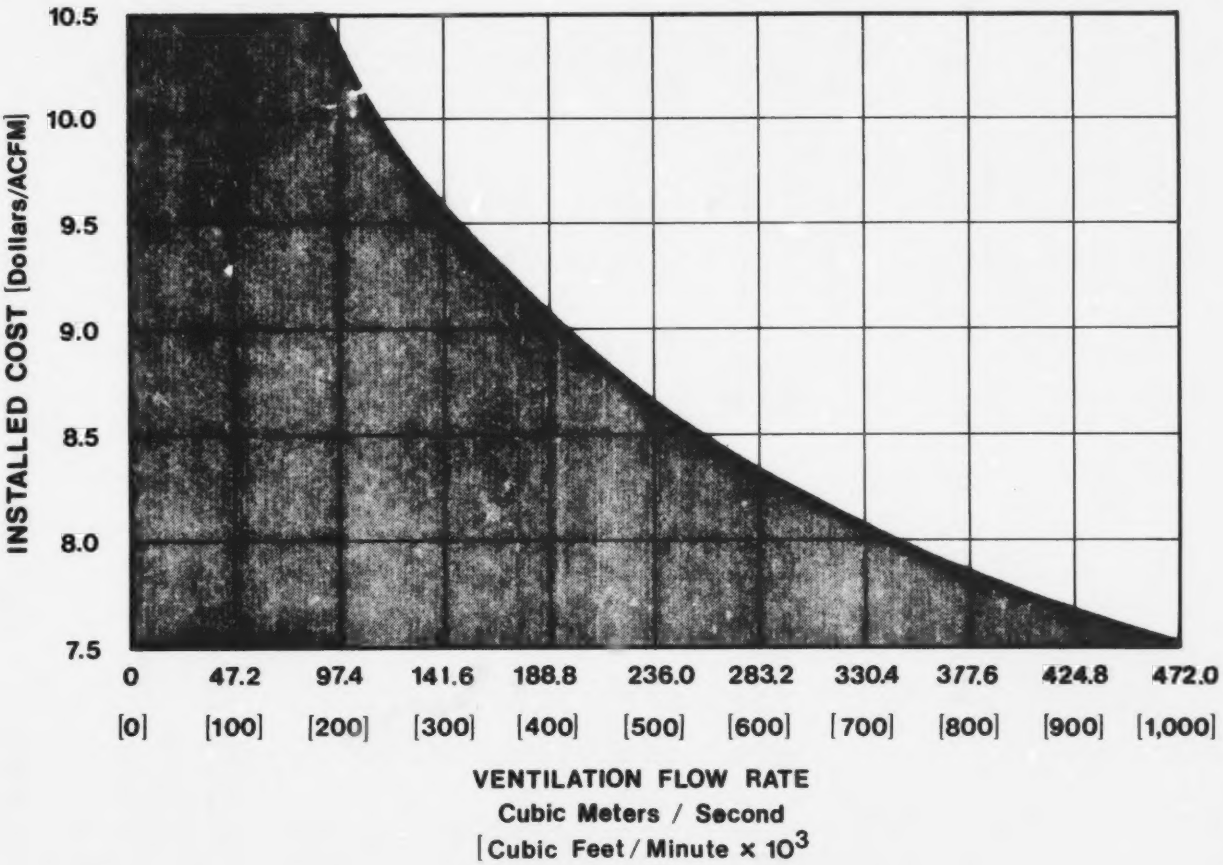


TABLE NO. 7-2
COST BREAKDOWN PER ANNUM OF 94.4 M3/SEC. (200,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	110,151.	109,710.	0.	87,768.	149,040.	49,746.	517,015.	.9259	478,717.
2	11,236.	116,760.	116,293.	0.	93,034.	145,060.	53,726.	536,109.	.8573	459,627.
3	11,910.	123,766.	123,270.	0.	98,616.	140,762.	58,024.	556,348.	.7938	441,647.
4	12,625.	131,192.	130,666.	0.	104,533.	136,120.	62,666.	577,802.	.7350	424,702.
5	13,382.	139,063.	138,506.	0.	110,805.	131,107.	67,679.	600,543.	.6806	408,719.
6	14,185.	147,407.	146,817.	0.	117,453.	125,693.	73,093.	624,648.	.6302	393,634.
7	15,036.	156,251.	155,626.	0.	124,501.	119,845.	78,941.	650,200.	.5835	379,386.
8	15,938.	165,626.	164,963.	0.	131,971.	113,529.	85,257.	677,284.	.5403	365,916.
9	16,895.	175,564.	174,861.	0.	139,889.	106,710.	92,076.	705,994.	.5002	353,173.
10	17,908.	186,098.	185,353.	42,980.	148,282.	99,343.	99,443.	779,407.	.4632	361,017.
11	18,983.	197,263.	196,474.	0.	157,179.	91,388.	107,398.	768,685.	.4289	329,676.
12	20,122.	209,099.	208,262.	0.	166,610.	82,796.	115,990.	802,879.	.3971	318,835.
13	21,329.	221,645.	220,758.	0.	176,606.	73,518.	125,268.	839,125.	.3677	308,545.
14	22,609.	234,944.	234,003.	0.	187,203.	63,495.	135,291.	877,545.	.3405	298,770.
15	23,966.	249,041.	248,044.	0.	198,435.	52,673.	146,113.	918,270.	.3152	289,478.
16	25,403.	263,983.	262,926.	0.	210,341.	40,983.	157,803.	961,439.	.2919	280,635.
17	26,928.	279,822.	278,702.	0.	222,961.	28,360.	170,426.	1,007,199.	.2703	272,215.
18	28,543.	296,611.	295,424.	0.	236,339.	14,724.	184,062.	1,055,703.	.2502	264,189.
							$1,863,000.			$6,428,875.
										$207,000.
										$6,635,875.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $24,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $2,070,000.
AMOUNT FINANCED = $1,863,000.

TABLE NO. 7-3
COST BREAKDOWN PER ANNUM OF 141.6 M3/SEC (300,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE		TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
						INTEREST (7)	PRINCIPAL			
1	10,600.	165,226.	151,580.	0.	121,264.	205,920.	68,732.	723,321.	.9259	669,742.
2	11,236.	175,140.	160,675.	0.	128,540.	200,422.	74,230.	750,242.	.8573	643,211.
3	11,910.	185,648.	170,315.	0.	136,252.	194,483.	80,168.	778,777.	.7938	618,219.
4	12,625.	196,787.	180,534.	0.	144,427.	188,070.	86,582.	809,025.	.7350	594,658.
5	13,382.	208,595.	191,366.	0.	153,093.	181,143.	93,508.	841,087.	.6806	572,430.
6	14,185.	221,110.	202,848.	0.	162,279.	173,663.	100,989.	875,073.	.6302	551,445.
7	15,036.	234,377.	215,019.	0.	172,015.	165,584.	109,068.	911,098.	.5835	531,618.
8	15,938.	248,439.	227,920.	0.	182,336.	156,857.	117,794.	949,285.	.5403	512,870.
9	16,895.	263,346.	241,595.	0.	193,276.	147,435.	127,216.	989,763.	.5002	495,128.
10	17,908.	279,146.	256,091.	64,470.	204,873.	137,257.	137,394.	1,097,140.	.4632	508,189.
11	18,983.	295,895.	271,457.	0.	217,165.	126,266.	148,385.	1,078,151.	.4289	462,401.
12	20,122.	313,649.	287,744.	0.	230,195.	114,394.	160,257.	1,126,361.	.3971	447,294.
13	21,329.	332,468.	305,009.	0.	244,007.	101,575.	173,076.	1,177,464.	.3677	432,951.
14	22,609.	352,416.	323,309.	0.	258,647.	87,727.	186,924.	1,231,632.	.3405	419,323.
15	23,966.	373,561.	342,708.	0.	274,166.	72,775.	201,876.	1,289,051.	.3152	406,363.
16	25,403.	395,974.	363,270.	0.	290,616.	56,623.	218,028.	1,349,915.	.2919	394,028.
17	26,928.	419,733.	385,066.	0.	308,053.	39,183.	235,468.	1,414,431.	.2703	382,277.
18	28,543.	444,917.	408,170.	0.	326,536.	20,344.	254,307.	1,482,817.	.2502	371,074.
							$2,574,000.			$9,013,214.
										$286,000.
										$9,299,214.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $36,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $2,860,000.
AMOUNT FINANCED = $2,574,000.

TABLE NO. 7-4
COST BREAKDOWN PER ANNUM OF 188.8 M3/SEC. (400,000 CFM) TOTLA EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

					PROPERTY	DEBT	SERVICE		PRESENT	PRESENT WORTH
YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	TAX INSURANCE (6,2)	INTEREST (7)	PRINCIPAL	TOTAL ANNUAL COSTS	WORTH MULTIPLIER (8)	TOTAL ANNUAL COST
1	10,600.	220,302.	190,800.	0.	152,640.	259,200.	86,515.	920,057.	.9259	851,904.
2	11,236.	233,520.	202,248.	0.	161,798.	252,279.	93,436.	954,517.	.8573	818,345.
3	11,910.	247,531.	214,383.	0.	171,506.	244,804.	100,911.	991,045.	.7938	786,724.
4	12,625.	262,383.	227,246.	0.	181,797.	236,731.	108,984.	1,029,765.	.7350	756,908.
5	13,382.	278,126.	240,881.	0.	192,704.	228,012.	117,703.	1,070,808.	.6806	728,774.
6	14,185.	294,814.	255,333.	0.	204,267.	218,597.	127,118.	1,114,313.	.6302	702,207.
7	15,036.	312,502.	270,653.	0.	216,523.	208,427.	137,288.	1,160,429.	.5835	677,100.
8	15,938.	331,252.	286,893.	0.	229,514.	197,443.	148,272.	1,209,312.	.5403	653,354.
9	16,895.	351,128.	304,106.	0.	243,285.	185,583.	160,132.	1,261,128.	.5002	630,878.
10	17,908.	372,195.	322,352.	85,961.	257,882.	172,771.	172,944.	1,402,013.	.4632	649,404.
11	18,983.	394,527.	341,694.	0.	273,355.	158,936.	186,779.	1,374,273.	.4289	589,403.
12	20,122.	418,199.	362,195.	0.	289,756.	143,993.	201,722.	1,435,986.	.3971	570,251.
13	21,329.	443,290.	383,927.	0.	307,141.	127,857.	217,858.	1,501,403.	.3677	552,063.
14	22,609.	469,888.	406,962.	0.	325,570.	110,426.	235,289.	1,570,744.	.3405	534,778.
15	23,966.	498,081.	431,380.	0.	345,104.	91,605.	254,110.	1,644,245.	.3152	518,336.
16	25,403.	527,966.	457,263.	0.	365,810.	71,274.	274,441.	1,722,157.	.2919	502,682.
17	26,928.	559,644.	484,699.	0.	387,759.	49,321.	296,393.	1,804,744.	.2703	487,767.
18	28,543.	593,222.	513,781.	0.	411,024.	25,608.	320,107.	1,892,285.	.2502	473,543.
							==========			--------------
							$3,240,000.			$11,484,410.
										$360,000.
										==============
										$11,844,410.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $48,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $3,600,000.
AMOUNT FINANCED = $3,240,000.

TABLE NO. 7-5
COST BREAKDOWN PER ANNUM OF 236 M3/SEC. (500,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	275,376.	227,900.	0.	182,320.	309,599.	103,338.	1,109,133.	.9259	1,026,975.
2	11,236.	291,899.	241,574.	0.	193,259.	301,333.	111,604.	1,150,905.	.8573	986,716.
3	11,910.	309,413.	256,068.	0.	204,855.	292,404.	120,533.	1,195,183.	.7938	948,775.
4	12,625.	327,978.	271,432.	0.	217,146.	282,762.	130,175.	1,242,118.	.7350	912,994.
5	13,382.	347,656.	287,718.	0.	230,175.	272,347.	140,590.	1,291,868.	.6806	879,224.
6	14,185.	368,516.	304,982.	0.	243,985.	261,101.	151,836.	1,344,604.	.6302	847,329.
7	15,036.	390,626.	323,280.	0.	258,624.	248,954.	163,983.	1,400,504.	.5835	817,181.
8	15,938.	414,064.	342,677.	0.	274,142.	235,834.	177,103.	1,459,758.	.5403	788,663.
9	16,895.	438,908.	363,238.	0.	290,590.	221,668.	191,269.	1,522,568.	.5002	761,663.
10	17,908.	465,242.	385,032.	107,451.	308,026.	206,365.	206,572.	1,696,596.	.4632	785,853.
11	18,983.	493,157.	408,134.	0.	326,507.	189,840.	223,097.	1,659,718.	.4289	711,825.
12	20,122.	522,746.	432,622.	0.	346,098.	171,991.	240,946.	1,734,525.	.3971	688,804.
13	21,329.	554,111.	458,579.	0.	366,863.	152,718.	260,219.	1,813,820.	.3677	666,938.
14	22,609.	587,358.	486,094.	0.	388,875.	131,898.	281,039.	1,897,873.	.3405	646,153.
15	23,966.	622,599.	515,260.	0.	412,208.	109,417.	303,520.	1,986,969.	.3152	626,376.
16	25,403.	659,955.	546,175.	0.	436,940.	85,133.	327,804.	2,081,410.	.2919	607,545.
17	26,928.	699,552.	578,946.	0.	463,156.	58,911.	354,025.	2,181,519.	.2703	589,598.
18	28,543.	741,525.	613,682.	0.	490,946.	30,587.	382,350.	2,287,634.	.2502	572,479.
							$3,869,998.			$13,865,082.
										$430,000.
										$14,295,082.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $60,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $4,300,000.
AMOUNT FINANCED = $3,870,000.

TABLE NO. 7-6
COST BREAKDOWN PER ANNUM OF 283.3 M3/SEC. (600,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

					PROPERTY	DEBT SERVICE			PRESENT	PRESENT WORTH
YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	TAX INSURANCE (6,2)	INTEREST (7)	PRINCIPAL	TOTAL ANNUAL COSTS	WORTH MULTIPLIER (8)	TOTAL ANNUAL COST
1	10,600.	330,453.	264,470.	0.	211,576.	359,279.	119,920.	1,296,298.	.9259	1,200,276.
2	11,236.	350,280.	280,338.	0.	224,271.	349,687.	129,512.	1,345,324.	.8573	1,153,398.
3	11,910.	371,297.	297,158.	0.	237,727.	339,325.	139,874.	1,397,291.	.7938	1,109,215.
4	12,625.	393,575.	314,988.	0.	251,990.	328,136.	151,063.	1,452,377.	.7350	1,067,541.
5	13,382.	417,189.	333,887.	0.	267,110.	316,049.	163,150.	1,510,767.	.6806	1,028,203.
6	14,185.	442,220.	353,920.	0.	283,136.	302,999.	176,200.	1,572,661.	.6302	991,044.
7	15,036.	468,754.	375,156.	0.	300,124.	288,903.	190,296.	1,638,269.	.5835	955,915.
8	15,938.	496,879.	397,665.	0.	318,132.	273,677.	205,522.	1,707,813.	.5403	922,679.
9	16,895.	526,691.	421,525.	0.	337,220.	257,238.	221,961.	1,781,530.	.5002	891,209.
10	17,908.	558,293.	446,816.	128,941.	357,453.	239,480.	239,719.	1,988,610.	.4632	921,112.
11	18,983.	591,790.	473,625.	0.	378,900.	220,302.	258,897.	1,942,498.	.4289	833,105.
12	20,122.	627,298.	502,043.	0.	401,634.	199,590.	279,609.	2,030,295.	.3971	806,259.
13	21,329.	664,936.	532,165.	0.	425,732.	177,223.	301,976.	2,123,361.	.3677	780,756.
14	22,609.	704,832.	564,095.	0.	451,276.	153,063.	326,136.	2,222,011.	.3405	756,509.
15	23,966.	747,122.	597,941.	0.	478,353.	126,974.	352,225.	2,326,579.	.3152	733,436.
16	25,403.	791,949.	633,817.	0.	507,054.	98,794.	380,405.	2,437,422.	.2919	711,461.
17	26,928.	839,466.	671,846.	0.	537,477.	68,365.	410,834.	2,554,915.	.2703	690,515.
18	28,543.	889,834.	712,157.	0.	569,726.	35,495.	443,704.	2,679,458.	.2502	670,533.
							$4,490,999.			$16,223,154.
										$499,000.
										$16,722,154.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $72,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $4,990,000.
AMOUNT FINANCED = $4,491,000.

TABLE NO. 7-7
COST BREAKDOWN PER ANNUM OF 330.4 M3/SEC. (700,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	385,528.	298,390.	0.	238,712.	405,359.	135,300.	1,473,890.	.9259	1,364,713.
2	11,236.	408,660.	316,293.	0.	253,035.	394,536.	146,123.	1,529,883.	.8573	1,311,629.
3	11,910.	433,180.	335,271.	0.	268,217.	382,845.	157,814.	1,589,237.	.7938	1,261,588.
4	12,625.	459,170.	355,387.	0.	284,310.	370,222.	170,437.	1,652,151.	.7350	1,214,381.
5	13,382.	486,721.	376,710.	0.	301,368.	356,584.	184,075.	1,718,841.	.6806	1,169,815.
6	14,185.	515,924.	399,313.	0.	319,450.	341,861.	198,799.	1,789,532.	.6302	1,127,709.
7	15,036.	546,879.	423,272.	0.	338,617.	325,957.	214,703.	1,864,464.	.5835	1,087,898.
8	15,938.	579,692.	448,668.	0.	358,934.	308,778.	231,881.	1,943,892.	.5403	1,050,225.
9	16,895.	614,473.	475,588.	0.	380,470.	290,230.	250,429.	2,028,086.	.5002	1,014,549.
10	17,908.	651,342.	504,123.	150,431.	403,299.	270,194.	270,465.	2,267,763.	.4632	1,050,414.
11	18,983.	690,422.	534,371.	0.	427,497.	248,558.	292,101.	2,211,932.	.4289	948,661.
12	20,122.	731,847.	566,433.	0.	453,146.	225,189.	315,471.	2,312,208.	.3971	918,211.
13	21,329.	775,758.	600,419.	0.	480,335.	199,953.	340,706.	2,418,501.	.3677	889,279.
14	22,609.	822,304.	636,444.	0.	509,155.	172,694.	367,965.	2,531,171.	.3405	861,766.
15	23,966.	871,642.	674,631.	0.	539,704.	143,259.	397,400.	2,650,602.	.3152	835,582.
16	25,403.	923,940.	715,108.	0.	572,087.	111,465.	429,195.	2,777,198.	.2919	810,639.
17	26,928.	979,377.	758,015.	0.	606,412.	77,133.	463,526.	2,911,390.	.2703	786,860.
18	28,543.	1,038,139.	803,496.	0.	642,797.	40,048.	500,612.	3,053,634.	.2502	764,170.
							==========			-------------
							$5,066,999.			$18,468,068.
										$563,000.
										=============
										$19,031,068.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $84,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $5,630,000.
AMOUNT FINANCED = $5,067,000.

TABLE NO. 7-8
COST BREAKDOWN PER ANNUM OF 377.6 M3/SEC. (800,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	440,604.	332,310.	0.	265,848.	451,439.	150,681.	1,651,481.	.9259	1,529,150.
2	11,236.	467,040.	352,249.	0.	281,799.	439,387.	162,733.	1,714,443.	.8573	1,469,859.
3	11,910.	495,062.	373,383.	0.	298,707.	426,366.	175,754.	1,781,182.	.7938	1,413,961.
4	12,625.	524,766.	395,786.	0.	316,629.	412,308.	189,812.	1,851,926.	.7350	1,361,222.
5	13,382.	556,252.	419,534.	0.	335,627.	397,120.	205,000.	1,926,914.	.6806	1,311,426.
6	14,185.	589,627.	444,706.	0.	355,764.	380,723.	221,397.	2,006,402.	.6302	1,264,374.
7	15,036.	625,005.	471,388.	0.	377,110.	363,011.	239,109.	2,090,659.	.5835	1,219,880.
8	15,938.	662,505.	499,671.	0.	399,737.	343,879.	258,241.	2,179,971.	.5403	1,177,771.
9	16,895.	702,255.	529,651.	0.	423,721.	323,223.	278,897.	2,274,642.	.5002	1,137,888.
10	17,908.	744,391.	561,430.	171,921.	449,144.	300,909.	301,211.	2,546,915.	.4632	1,179,716.
11	18,983.	789,054.	595,116.	0.	476,093.	276,813.	325,307.	2,481,366.	.4289	1,064,216.
12	20,122.	836,397.	630,823.	0.	504,659.	250,788.	351,332.	2,594,120.	.3971	1,030,162.
13	21,329.	886,581.	668,673.	0.	534,938.	222,684.	379,436.	2,713,640.	.3677	997,801.
14	22,609.	939,776.	708,793.	0.	567,034.	192,325.	409,795.	2,840,331.	.3405	967,023.
15	23,966.	996,162.	751,320.	0.	601,056.	159,545.	442,575.	2,974,624.	.3152	937,727.
16	25,403.	1,055,932.	796,400.	0.	637,120.	124,136.	477,984.	3,116,974.	.2919	909,816.
17	26,928.	1,119,288.	844,183.	0.	675,347.	85,901.	516,218.	3,267,865.	.2703	883,204.
18	28,543.	1,186,445.	894,834.	0.	715,868.	44,600.	557,520.	3,427,810.	.2502	857,808.
							==========			--------------
							$5,642,999.			$20,712,984.
										$627,000.
										==============
										$21,339,984.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $96,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $6,270,000.
AMOUNT FINANCED = $5,643,000.

TABLE NO. 7-9
COST BREAKDOWN PER ANNUM OF 424.8 M3/SEC. (900,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

					PROPERTY	DEBT SERVICE			PRESENT	PRESENT WORTH
YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	TAX INSURANCE (6,2)	INTEREST (7)	PRINCIPAL	TOTAL ANNUAL COSTS	WORTH MULTIPLIER (8)	TOTAL ANNUAL COST
1	10,600.	495,680.	365,170.	0.	292,136.	496,078.	165,581.	1,825,246.	.9259	1,690,042.
2	11,236.	525,421.	387,080.	0.	309,664.	482,834.	178,825.	1,895,061.	.8573	1,624,710.
3	11,910.	556,946.	410,305.	0.	328,244.	468,527.	193,132.	1,969,065.	.7938	1,563,108.
4	12,625.	590,363.	434,923.	0.	347,939.	453,077.	208,582.	2,047,509.	.7350	1,504,981.
5	13,382.	625,785.	461,019.	0.	368,815.	436,388.	225,271.	2,130,660.	.6806	1,450,092.
6	14,185.	663,332.	488,680.	0.	390,944.	418,369.	243,290.	2,218,800.	.6302	1,398,221.
7	15,036.	703,132.	518,000.	0.	414,400.	398,906.	262,753.	2,312,228.	.5835	1,349,164.
8	15,938.	745,320.	549,080.	0.	439,264.	377,883.	283,776.	2,411,262.	.5403	1,302,731.
9	16,895.	790,039.	582,025.	0.	465,620.	355,184.	306,476.	2,516,238.	.5002	1,258,747.
10	17,908.	837,441.	616,947.	193,411.	493,557.	330,664.	330,995.	2,820,924.	.4632	1,306,635.
11	18,983.	887,688.	653,963.	0.	523,171.	304,185.	357,474.	2,745,464.	.4289	1,177,484.
12	20,122.	940,949.	693,201.	0.	554,561.	275,586.	386,073.	2,870,492.	.3971	1,139,913.
13	21,329.	997,406.	734,793.	0.	587,835.	244,703.	416,956.	3,003,022.	.3677	1,104,206.
14	22,609.	1,057,250.	778,881.	0.	623,105.	211,343.	450,316.	3,143,504.	.3405	1,070,242.
15	23,966.	1,120,685.	825,614.	0.	660,491.	175,321.	486,339.	3,292,414.	.3152	1,037,908.
16	25,403.	1,187,926.	875,150.	0.	700,120.	136,411.	525,249.	3,450,259.	.2919	1,007,099.
17	26,928.	1,259,201.	927,659.	0.	742,127.	94,395.	567,264.	3,617,575.	.2703	977,720.
18	28,543.	1,334,753.	983,319.	0.	786,655.	49,010.	612,649.	3,794,930.	.2502	949,679.
							==========			--------------
							$6,200,999.			$22,912,660.
										$689,000.
										==============
										$23,601,660.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $108,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $6,890,000.
AMOUNT FINANCED = $6,201,000.

TABLE NO. 7-10
COST BREAKDOWN PER ANNUM OF 472 M3/SEC. (1,000,000 CFM) TOTAL EVACUATION SYSTEM
BASED ON 18 YEAR LIFE

YEAR	LABOR (1,2)	ELECTRIC (3,2)	MAINTENANCE (4,2)	BAGS (5,2)	PROPERTY TAX INSURANCE (6,2)	DEBT SERVICE INTEREST (7)	DEBT SERVICE PRINCIPAL	TOTAL ANNUAL COSTS	PRESENT WORTH MULTIPLIER (8)	PRESENT WORTH TOTAL ANNUAL COST
1	10,600.	550,756.	397,500.	0.	318,000.	539,998.	180,241.	1,997,095.	.9259	1,849,162.
2	11,236.	583,801.	421,350.	0.	337,080.	525,582.	194,657.	2,073,706.	.8573	1,777,869.
3	11,910.	618,829.	446,631.	0.	357,305.	510,008.	210,231.	2,154,914.	.7938	1,710,641.
4	12,625.	655,959.	473,429.	0.	378,743.	493,190.	227,049.	2,240,994.	.7350	1,647,198.
5	13,382.	695,316.	501,834.	0.	401,468.	475,025.	245,214.	2,332,239.	.6806	1,587,284.
6	14,185.	737,035.	531,944.	0.	425,556.	455,409.	264,830.	2,428,959.	.6302	1,530,657.
7	15,036.	781,257.	563,861.	0.	451,089.	434,223.	286,016.	2,531,483.	.5835	1,477,097.
8	15,938.	828,133.	597,693.	0.	478,154.	411,339.	308,900.	2,640,157.	.5403	1,426,396.
9	16,895.	877,821.	633,554.	0.	506,843.	386,631.	333,608.	2,755,352.	.5002	1,378,363.
10	17,908.	930,490.	671,568.	214,902.	537,254.	359,939.	360,300.	3,092,360.	.4632	1,432,363.
11	18,983.	986,319.	711,862.	0.	569,489.	331,116.	389,123.	3,006,892.	.4289	1,289,606.
12	20,122.	1,045,498.	754,573.	0.	603,659.	299,985.	420,254.	3,144,091.	.3971	1,248,563.
13	21,329.	1,108,228.	799,848.	0.	639,878.	266,368.	453,871.	3,289,522.	.3677	1,209,552.
14	22,609.	1,174,722.	847,838.	0.	678,271.	230,054.	490,185.	3,443,679.	.3405	1,172,440.
15	23,966.	1,245,205.	898,709.	0.	718,967.	190,843.	529,396.	3,607,085.	.3152	1,137,105.
16	25,403.	1,319,917.	952,631.	0.	762,105.	148,488.	571,751.	3,780,295.	.2919	1,103,434.
17	26,928.	1,399,112.	1,009,789.	0.	807,831.	102,753.	617,486.	3,963,899.	.2703	1,071,321.
18	28,543.	1,483,059.	1,070,376.	0.	856,301.	53,349.	666,890.	4,158,518.	.2502	1,040,667.
							$6,749,998.			$25,089,688.
										$750,000.
										$25,839,688.

1. CURRENT LABOR - $10,000.
2. INFLATION - 6.0%
3. $.030/KWH
4. 5.0% OF CAPITAL
5. BAG COSTS - $120,000.
6. 4.0% OF CAPITAL
7. 8.0%
8. AT 8.0%

CAPITAL COSTS = $7,500,000.
AMOUNT FINANCED = $6,750,000.

Little report to AISI entitled "Steel and the Environment, A Cost Impact Analysis", dated May 1975 (page B-17, Fabric Filter System, High Complexity) inflated to 1976 costs using the Engineering News Record Construction Cost Index.

Figure 7-21 charts coal consumption to provide electrical power required by a total cast house evacuation control system.

PARTIAL CONTROL VS. TOTAL CONTROL

As the values presented on Figures 7-14 and 7-18 indicate, capture of 100% of the fugitive emissions generated during casting will require better than 450% of the energy necessary to capture 70% of the generated emissions by partial control. If it is determined that 50% capture is achievable with the partial control concept, then increasing emission capture to 100% will require increasing energy consumption by better than 4 1/2 times. In addition to energy consumption, total control or 100% capture will increase power house emissions (particulate matter, SO_x and NO_x) also by 450% when compared to power house emissions created by partial control assuming no improvement in power house emission control.

As evidenced here, the incremental increase in fugitive emission capture efficiency to 100% becomes increasingly more costly in energy consumed as well as power house emission standpoints.

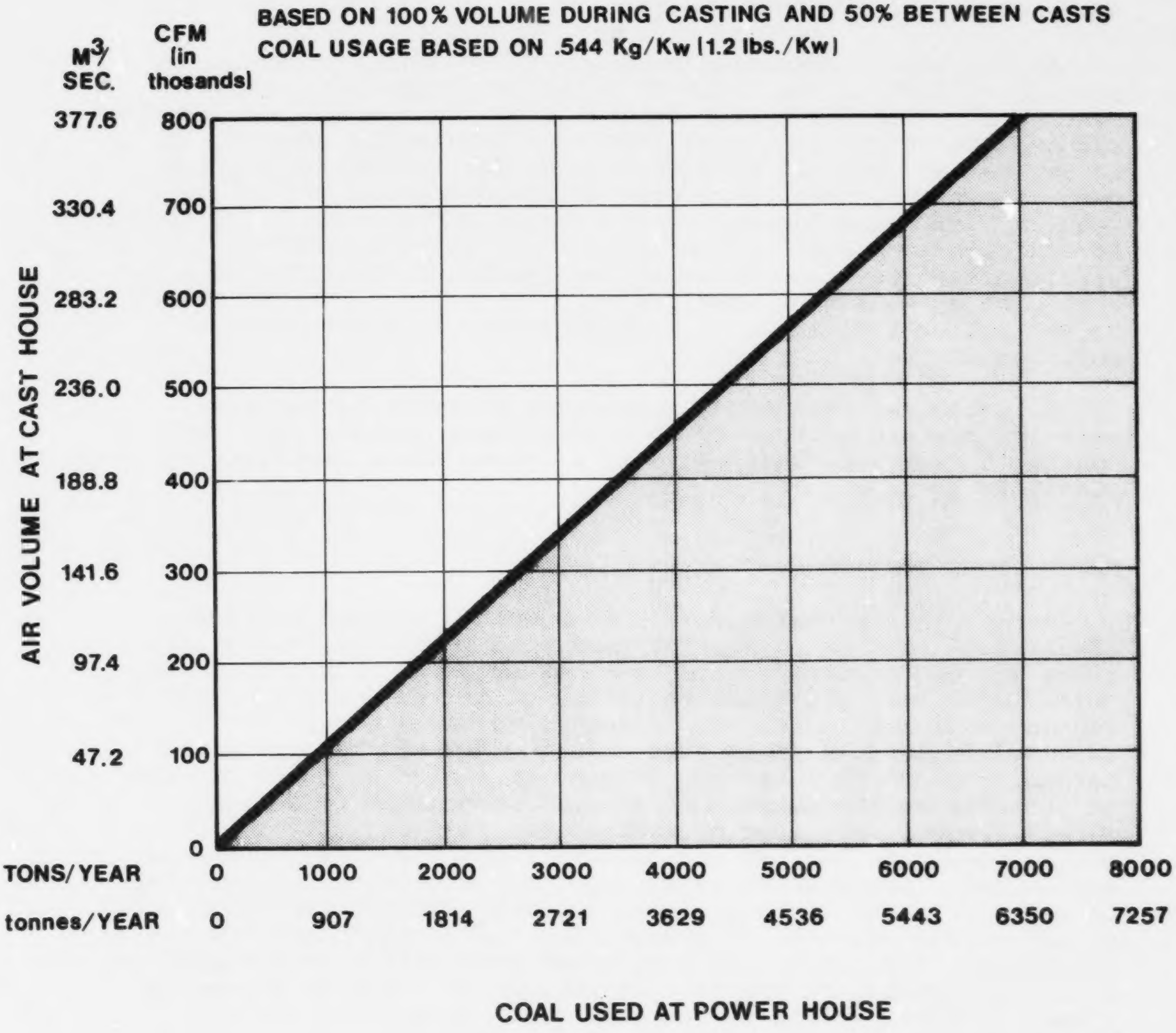
SAFETY CONSIDERATIONS

Safety in the cast house is accentuated through continuing educational programs. Meetings are held regularly, and strict rules are enforced to ensure that safety programs are followed. There is a rigid procedure to follow on all production operations and any equipment which may be installed would add to the danger involved in pursuing normal functions and would be considered a hazard. Hoods which are in the line of vision or which provide an obstacle in the working zone would be considered a negative safety factor. Any type of obstruction must be kept at a clear height above the working area and must not interfere with crane operations. Hoods which swing away, or which must be activated in any way, create an additional occupational problem which adds to the normal sequence of operations. To create a permissible environment for labor, the cast house must either remain open for fresh air intake, or the evacuation must be complete enough to create an equal volume of inspired air. Otherwise, working conditions may not be acceptable and OSHA problems could be created.

If localized ventilation methods (close fitting hoods and covers) are considered as a means to lower ventilation volumes

Figure 7-21

FUEL CONSUMPTION FOR TOTAL EVACUATION OF CAST HOUSE



and thus energy requirements, the safety factor must be regarded as a major consideration. If a partial-control, flexible curtain type of enclosure is installed, reinforcement or additional precautions must be taken to ensure worker safety. For example, a precaution might be to prohibit working beneath the curtain during casting, but enforcement could be difficult.

SECTION 8

CLASSIFICATIONS OF EXISTING UNITED STATES BLAST FURNACES

United States blast furnaces may be categorized into groups related to fume control while casting. Grouping considers potential fume emissions from production of hot metal, the physical characteristics of the cast houses, and the casting operations.

Class one - All cast houses with single tap hole furnaces. This group of blast furnaces totals 140 (93% of the 151 blast furnace operations recorded in Table A-5). The geometry of the cast houses in this group varies widely (the physical configurations of these cast houses have been presented in Section 4 of this report.) Because these are all single tap hole furnaces, there would probably be insufficient time between casts to maintain close fitting tap hole, trough and runner hooding. If it is subsequently determined that a level of control greater than that which is possible with process changes is desired, these furnaces could be candidates for additional control using the partial control method of overhead hooding of the tap hole and iron trough areas. The angle of the tap hole may preclude any close fitting hoods at the iron trough because the trajectory of the hot metal would cause impingement of molten iron on the refractory lining of the hoods. Most of the cast houses would not have available space to store spare parts and maintain runner hooding.

Additionally, the ductwork of the close fitting covers and hoods which is required to convey the captured emissions to an exterior control device must run beneath the cast house floor in order not to interfere with normal iron making activities, including crane movement. Because most of the cast houses in this group have backfilled cast house floors, the routing of extensive lengths of large diameter ductwork underground is not technically feasible from access and maintenance standpoints.

Total cast house evacuation which is thought to require 60 or more cast house volume air changes per hour is a technically feasible method of controlling cast house fumes, but because of the enormous volumes of air that would have to be handled, it becomes very energy intensive. This approach would require closing most of the existing open areas in the sides of the cast house structure in order to produce a controlled in-draft condition, which could cause labor difficulties and necessitate additional increases in the evacuation rate to meet OSHA requirements.

Class two - cast houses with blast furnaces having multiple tap holes.

A total of 11 of the blast furnace operations recorded in Table A-5 fall into this grouping.

A detailed study of specific cast houses in both class one and class two would disclose to what extent process changes could reduce emissions. Because this group of blast furnace cast houses tends to have (but not in all cases) less congested interiors and open areas underneath the floor (not backfilled), they appear to lend themselves to the use of close fitting hoods and covers over the runners and pouring spouts. However, the tap holes have been designed with elevated angles and could create a serious problem for close fitting hoods and covers at the iron trough. This type of hooding was applied at Gary No. 13 blast furnace for the purpose of controlling hot metal splashing and was found to be impractical due to frequent upsets which included coke messes. However, a partial control system employing the retractable enclosure concept could be applied to multiple tap hole furnaces as discussed for single tap hole furnaces.

Total evacuation while technically feasible, may not be practical for the same reason as stated in class 1.

Class three - new furnace cast houses not yet in the engineering stage. The engineering of these furnaces could be undertaken with total control in mind. If the Japanese concept can be successfully applied to domestic operations, then good fume control would be guaranteed. These furnaces would probably be in the over 5,000 tonnes per day capacity range. The control concept for these furnaces is discussed in Section 9. It must be pointed out, however, that the direct application of the existing foreign technology to United States operations has not yet been successfully demonstrated. There are iron making operational differences between United States and Japanese Steel producers, and to what extent these differences may preclude successful application of this Japanese control technology, can only be assessed after operations at Sparrows Point, Md. and East Chicago, Ind. have been initiated and evaluated.

SECTION 9

CONCEPT DESIGNS FOR EMISSION CONTROL ON NEW BLAST FURNACE CAST HOUSES

This study defines new blast furnace cast houses as those on which engineering work has not yet started and which are designed as completely new furnaces rather than rebuilt versions or modifications of an existing furnace.

All new furnaces could be designed with facilities which could possibly achieve the no-visibility emission level of compliance. Essentially, the design would use the total control concept: close fitting hoods at the tap hole, iron trough and skimmer and the runners and spouts as used at the Japanese plants. This system could be used in conjunction with a large moveable hood in the tap hole and iron trough zone.

Japanese collection facilities consist of either vertical or horizontal hoods at the tap hole, close fitting dome covers and hoods over the iron trough, slag, hot metal runners, and pouring spouts. There must be an open area beneath the cast house floor to accept the transfer ducts that would run to the control device. The most suitable control device would be a positive baghouse with intermittent cleaning features. The application of other control devices, such as wet scrubbers and mechanical collectors, is possible if collection efficiencies are satisfactory. Depending upon specific features of the blast furnace and cast house, the primary system, or hooded runners, would be controlled by an order-of-magnitude ventilation rate of about 166 to 200 cubic meters per second (350,000 to 425,000 CFM) per tap hole operation; i.e., if it is possible to cast from two tap holes simultaneously, then the ventilation rate would double. Approximate allocation of the ventilation air would be 33 cubic meters per second (70,000 CFM) at the iron notch, 33 cubic meters per second (70,000 CFM) over the trough, 25 cubic meters per second (53,000 CFM) over the skimmer, and 100 cubic meters per second (212,000 CFM) over all spouts. Pick-up ducts from the pouring spouts could possibly be designed as either top or side draft hoods. The secondary system, which would probably be required for no-visible emissions, could have an order-of-magnitude ventilating capability of 125 cubic meters per second (265,000 CFM) per simultaneous tap hole operation.

Refractory lined covers over the trough and runners must be designed to be removeable by overhead crane for maintenance. Like the Japanese systems, most of the dust would be collected by the primary or hooded system. Operations at the tap hole would, of course, be carried out with the trough cover removed; and during this time the secondary or zoned capture system over the tap hole and trough would be activated to pick up all the fumes until the trough cover collection system is activated.

Assumptions could be made that all new furnaces would be designed with a tap hole angle which would reduce the possibility of hot metal coming in contact with hoods and covers during casting and would have improved operating conditions to minimize upset conditions such as coke messes and wild casts. B.E.E. does not know at this time if this design is feasible. Consequently, the feasibility of close fitting hoods and covers in the tap hole and iron trough areas must be demonstrated further. In order to keep maintenance of hoods and covers over iron and slag runners (that part of the hot metal conveying system downstream of the skimmer) to a minimum, the cast house should be designed to keep these runners as short as possible.

Secondary or moveable hoods or hood enclosures would drop down or be swung into position to a sufficient height above the cast house floor to allow movement of the drill and mud gun underneath. Hoods would be constructed of suitable materials to keep maintenance and safety hazards to a minimum. Assuming that a primary system of close fitting hoods and covers could be applied in the tap hole and iron trough zone, the retractable overhead hood or enclosure would only be moved into position and activated when the tap hole is drilled or closed. If it is not possible to use close fitting hoods and covers in this zone, then the secondary system or retractable overhead enclosure would be used during the complete casting cycle.

In some European cast houses the runner hoods had a large cross sectional area which lowered the velocity of the hot gases drawn into the ventilation ducts. This was done to reduce wear and erosion at the top corners of the runners caused by gas velocities in the hoods and covers.

New cast houses would have to provide maintenance space and storage for replacement hoods. Consideration should be given to ramp access to the cast house and the use of mobile cranes rather than the overhead types now in use. If this mobile crane would be technically feasible, it's use could provide greater flexibility of hood arrangements.

Because it is expected that most new furnaces will be larger, the platform or grating at the bustle pipe area could be high enough to permit handling of tap hole hoods beneath. On the larger furnaces, mobile cranes could operate from the platform.

Large furnaces now under construction by Bethlehem Steel at Sparrows Point, Maryland and by Inland Steel in Indiana, will demonstrate the applicability and feasibility of the close fitting cover and hood technology that is presently used by the Japanese. After these furnaces have been operated long enough to determine the extent of maintenance and production problems and to engineer modifications to improve the system, it can then be determined whether these systems can be made adaptable to the United States methods of operation.

An order-of-magnitude (>±30%) cost of equipment and installation for a control system of 708 cubic meters per second (1,500,000 CFM) and based on 1972 Japanese costs for equipment at Oita, would be approximately $11,300,000 in inflated 1976 dollars. This figure is based on ventilation rates required if two tap holes are cast simultaneously, as is the case with certain Japanese blast furnaces. This estimated cost could vary significantly depending on local conditions.

SECTION 10
ADDITIONAL RESEARCH AND DEVELOPMENT FOR THE CONTROL OF CAST HOUSE EMISSIONS

The following additional studies are deemed necessary by B.E.E. to pursue the concepts advanced in Section 7. These studies were not possible under the scope of this contract, due to limitations of time and monies. In order to provide needed reliable data to establish viable strategies for the control of cast house emission, these further efforts should be undertaken. An approximate time schedule for the performance of these studies appears on the following page as Figure No. 10-1.

1. Particulate and Gaseous Sampling

The concentration of particulates has not been satisfactorily established due to wide variations at different sites and by different measurement methods. The emission factors noted in this report have not been established as reliable due to limited data collection. Emissions from cast houses should be quantified and classifed to the extent that the statistical results will furnish data which could not readily be disputed.

To achieve a data base applicable to all basic iron furnaces, selection of proper sources should be a primary consideration in order to ensure overall coverage.

Testing results should include particulate size and composition data, gaseous quantification as well as qualification, and particulate matter concentrations. Testing would be performed using EPA methods or approved modifications.

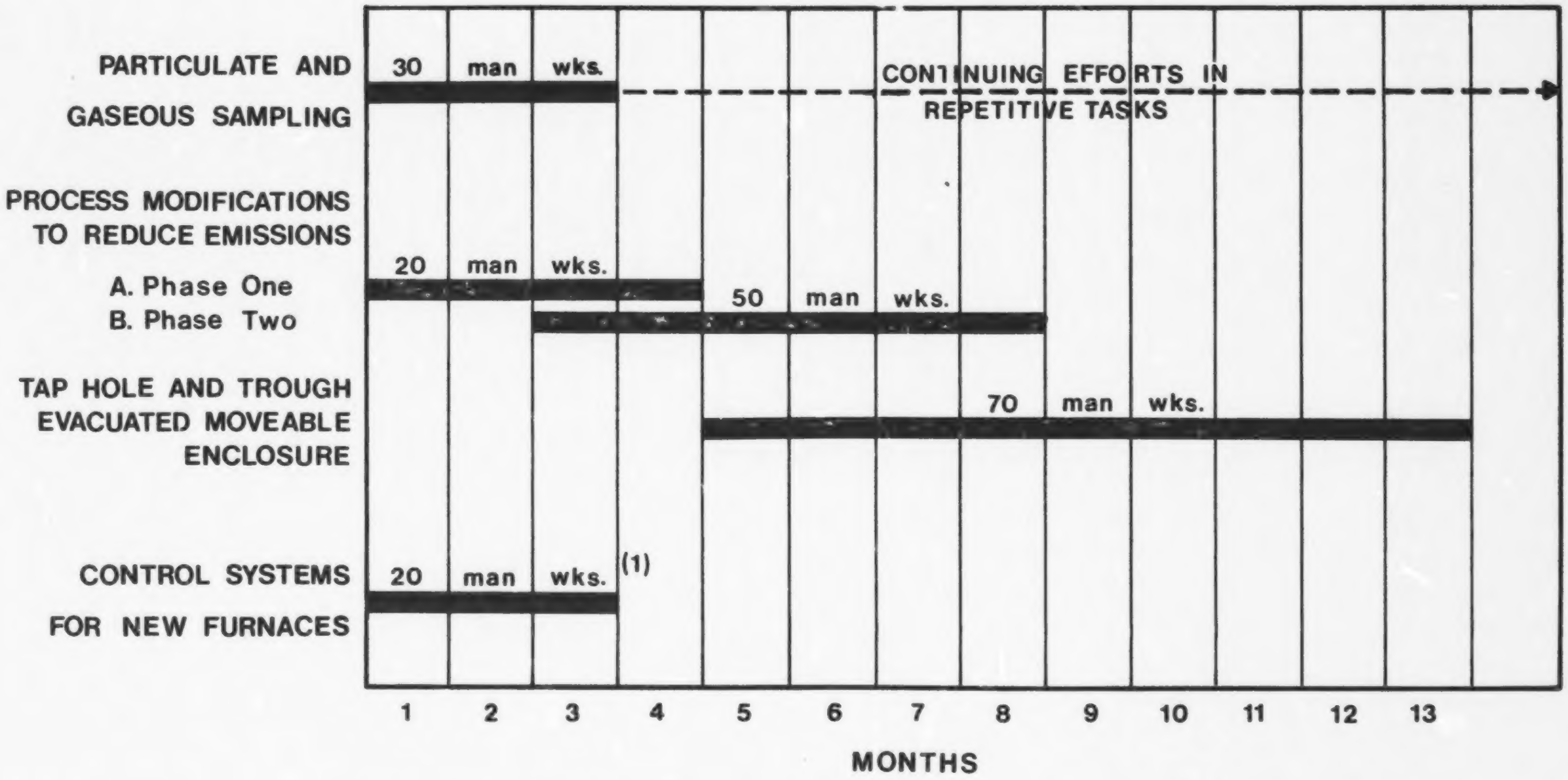
The sampling should be accomplished in repeated tasks along with other phases of an extended study. Each task would require about 3 months to complete and would consume about 30 man weeks of effort. Tasks would be performed at sites employing emission capture systems as they come on line and would provide a more reliable base for design engineering than is now available. It is estimated that at least two of these tasks would be required at a cost of $35,000 each or $70,000.

2. Process Modifications to Reduce Emissions

This study should be a two-phase effort; the first phase to be a paper study to determine the potential for emission reduction as well as the need and degree of effort to be extended in phase two for process modifications including materials, practices and procedures. The second phase would be a detailed study of the areas prescribed by phase one.

Figure 10–1

APPROXIMATE TIME SCHEDULE
ADDITIONAL R & D EFFORTS
CONTROL OR CAST HOUSE EMISSION



(1) Phase cannot be initiated until normal operations are attained at new facilities employing close fitting hoods and covers.

a. Phase One

This paper study should be a search and rating, in decreasing order of potential, of modifications to effect emission reduction at the source. Additionally, this phase should assess the extent to which modifications should be pursued in Phase Two. Extensive contacts would be made with material suppliers, operating personnel and engineers. A literature search should be included to gather all existing data. This study would require about 4 months at a cost of about $25,000.

Some of the items evaluated in this study could be:

1. Materials
    a. Tap Hole Clays
    b. Trough and Runner Lining
    c. Burden Materials
2. Operating Practices
    a. Furnace Charging Techniques
    b. Soaking Bar
    c. Preheated Ladles
    d. Wind Volumes, Pressure and Temperature
3. Cast House Characteristics
    a. Tap Hole Size
    b. Trough Dimensions
    c. Runner Dimensions
    d. Pouring Spout Type

b. Phase Two

This effort could start at the time phase one has been sufficiently researched to provide a base for further work. This study would be a demonstration effort to quantitatively assess performance of pre-selected process modifications and materials in reducing generated emissions. This phase should be conducted by steel company engineers or their designates.

A manpower effort of approximately 1 man year would be required and could be started during the phase one study. The estimated cost would be approximately $75,000 plus materials.

3. Tap Hole and Trough Evacuated Moveable Enclosure

The partial control method of a retractable curtain or hood at the iron trough should be investigated by selecting a suitable preliminary design and demonstrating its effectiveness by testing an installation at a selected site. This effort should be conducted by a steel firm and should require about 70 man weeks over a 6-month period at a cost of about $100,000 plus materials. For economic reasons, this project should be a continuance of the effort which has been initiated by Bethlehem Steel Corporation of Bethlehem, Pa. The benefits of this activity are that it would culminate in a determination of the total feasibility of this concept including capture performance, operational consideration as well as engineering details.

4. Control Systems for New Furnaces

This study would be an operating and performance evaluation of the new United States installations, employing the close fitting hood and cover emission control concept. This effort would require access to data from domestic steel firms as they accumulate operating information from their producing furnaces. The cost of this program would be about $30,000 and should not be initiated until after the systems are operational for sufficient time to attain normal conditions. The benefits of this program would be an accurate assessment of technology as applied to United States practices with recommendations for revisions to tailor the concepts to domestic practices for future applications.

Sampling of these installations could be conducted as a task under R&D effort No. 1 "Particulate and Gaseous Sampling".

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GLOSSARY

basicity: ratio of percent of CaO to percent of SiO_2 in slag (a dimensionless number)

bosh: the inverted conical section between the top of the hearth and the shell of the furnace itself. This section is normally three to four meters high.

burden: the materials which are charged into the top of the furnace. Materials are ores, sinter, ore pellets and slag, scrap, coke, and limestone.

bustle pipe: a plenum which receives the hot blast from the stove and distributes it to the tuyeres. The bustle pipe completely encircles the furnace and accepts hot air and temperatures as high as 1093°C (2,000°F).

cast house: is the structure which is built around the furnace and houses all the operations which occur during casting.

coke breeze: coke fines

coke mess: a condition occurring at the iron trough when large quantities of coke breeze are ejected from the tap hole.

cold blast: the air which is introduced beneath the burners in the stove.

dam: an obstruction placed in the iron trough at the point where the hot metal is separated from the slag. One design of this function is called the baker dam.

direct reduction: a process to produce steel directly from iron ore or to make a product equivalent to blast furnace pig iron for use in present steel making processes. This process could be considered an alternate to the blast furnace.

ferromanganese: a material made in blast furnaces from manganese ore or mixtures of manganese ore and iron ore. This material has a considerably lower percentage of iron than the pig iron normally produced in a blast furnace.

flux: material such as limestone which is introduced into the furnace to assist in the separation of slag from the molten iron. This material will vary depending upon the amounts and types of impurities that are to be removed.

fuel injection: secondary fuel which is injected at the tuyeres to add energy and to help control the temperature of the hearth. These fuels could be tar, fuel oil, gas or coke breeze.

hearth: the section below the bosh which holds the molten metal which is separated from the slag. The fuel which is injected at the tuyeres is injected into this area and the outlet or tap hole is drilled into this area.

hot blast: heated air from the stoves which is introduced through the tuyeres to ignite and burn the coke.

iron ladles: torpedo shaped cars with an opening at the top which are used to convey the hot metal from the blast furnace area to the steel making area. These cars are emptied by rotating about the axis, and pouring into the steel making equipment.

iron trough: the area directly outside the tap hole which holds the hot metal and separates the slag from the iron. The iron trough or pool has a dam built into one end with a skimmer to prevent the slag from entering the hot metal runners.

kish: carbon or graphite material that forms a portion of the air pollution when it is released from the hot metal upon cooling.

mud gun: the device which plugs the tap hole by ramming specially prepared refractory materials into the opening at the end of the cast when the iron level in the heartn becomes low.

pellets: a form of ore in which the iron particles have been agglomerated and mixed with a fuel and binder to form a larger size material for the burden.

pig iron: a term applied to the iron which is cast from blast furnaces and used in the manufacture of steel or castings.

pouring spouts: These are outlet pieces at the end of the runners which direct the molten slag or iron into the ladle cars.

pre-reduced burden: step in the iron making process preceding the blast furnace in which the ore is reduced thus abetting the blast furnace reduction process.

runners: ditches formed in the cast house floor made from a combination of materials built up in layers to convey hot metal and slag to the pouring spouts.

sinter: material formed by agglomerating fine ores and other materials on a moving heated belt. Sintered material may be a combination of fluxes, coke, and iron.

skimmer: a spade type appliance located above the dam which prevents the slag from following the path of the iron runners.

slag: material formed by the fluxes, such as limestone and consisting of undesireable materials in the burden.

slag ladles: open type ladles which convey the slag to a disposal area.

slag notch: an opening in the hearth above the hot metal tap hole which could be used to flush the slag from the top of the molten bath. The slag notch is normally called a monkey and it is closed by a metal plug.

stoves: brick lined heat regenerators which produce the hot blast used to ignite and burn the coke in the blast furnace. There are usually three to four stoves attached to each blast furnace to insure a constant supply of hot blast to the bustle pipe.

tap hole: the opening in the hearth which is used to withdraw the hot metal and slag from the furnace during casting.

tap hole drill: a hydraulic drill, which, when swung into position in front of the tap hole, is used to drill through the clay into the hearth to release the hot metal into the pool. A tap hole drill is usually about forty to sixty millimeters in diameter.

top gas: the combustible CO rich gas which is withdrawn from the top of the furnace and is used to heat the air in the stoves.

tuyeres: nozzle-type, high velocity openings which provide the inlets for the hot blast to the hearth area. Tuyeres receive the hot gas from the bustle pipe and inject it into the hearth.

tilting spout: a form of pouring spout in which the spout itself could be used to direct the flow from the runners to one or two different locations by tilting in the direction of pour.

working volume: the inside volumetric content of the furnace from the center line of the tuyeres to the stock line at the top of the furnace. This could be considered as the cubicle content of the burden in the furnace.

APPENDICES

A. PRODUCTION DATA FROM BLAST FURNACES

TABLE A-1
AVERAGES OF VALUES OBTAINED FROM QUESTIONNAIRE SURVEY OF STEEL MILLS
ENGLISH UNITS
CLASS 1

Reproduced from best available copy.

MINIMUM WORKING VOLUME (CU FT)	MAXIMUM WORKING VOLUME (CU FT)	AVG WORKING VOLUME (CU FT)	MINIMUM RECORD DAILY PROD HOT METAL (SHORT TONS)	MAXIMUM RECORD DAILY PROD HOT METAL (SHORT TONS)	AVG RECORD DAILY PROD HOT METAL (SHORT TONS)	MINIMUM CURRENT DAILY PROD HOT METAL (SHORT TONS)	MAXIMUM CURRENT DAILY PROD HOT METAL (SHORT TONS)	AVG CURRENT DAILY PROD HOT METAL (SHORT TONS)	MINIMUM NO. OF CASTS PER DAY	MAXIMUM NO. OF CASTS PER DAY
16,339	59,035	40,578	1,057	4,294	2,436	0	3,250	1,801	0	9

AVG NO. OF CASTS PER DAY	MINIMUM HEARTH DIAMETER (FEET)	MAXIMUM HEARTH DIAMETER (FEET)	AVG HEARTH DIAMETER (FEET)	MINIMUM IRON NOTCH BIT SZ. (IN)	MAXIMUM IRON NOTCH BIT SZ. (IN)	AVG IRON NOTCH BIT SZ. (IN)	MINIMUM NO. OF IRON NOTCHES	MAXIMUM NO. OF IRON NOTCHES	AVG NO. OF IRON NOTCHES	MINIMUM NO. OF CINDER NOTCHES	MAXIMUM NO. OF CINDER NOTCHES	AVG NO. OF CINDER NOTCHES	MINIMUM IRON TROUGH LENGTH (FEET)
7	15.12	31.00	25.31	2.25	4.00	3.22	1	1	1	0	2	1	8

MAXIMUM IRON TROUGH LENGTH (FEET)	AVG IRON TROUGH LENGTH (FEET)	MINIMUM IRON TROUGH WIDTH (IN.)	MAXIMUM IRON TROUGH WIDTH (IN.)	AVG IRON TROUGH WIDTH (IN.)	MINIMUM IRON TROUGH DEPTH (IN.)	MAXIMUM IRON TROUGH DEPTH (IN.)	AVG IRON TROUGH DEPTH (IN.)	MINIMUM DUR OF CAST (MIN)	MAXIMUM DUR OF CAST (MIN)	AVG DUR OF CAST (MIN)	MINIMUM DUR OF FLUSH (MIN)	MAXIMUM DUR OF FLUSH (MIN)	AVG DUR OF FLUSH (MIN)	MINIMUM BEGIN. BLAST PRESS (PSIG)
32	22	6	72	42	2	60	26	25	90	46	12	180	40	15

MAXIMUM BEGIN. BLAST PRESS (PSIG)	AVG BEGIN. BLAST PRESS (PSIG)	MINIMUM BEGIN. BLAST VOLUME (SCFM)	MAXIMUM BEGIN. BLAST VOLUME (SCFM)	AVG BEGIN. BLAST VOLUME (SCFM)	MINIMUM STOPPED BLAST PRESS (PSIG)	MAXIMUM STOPPED BLAST PRESS (PSIG)	AVG STOPPED BLAST PRESS (PSIG)	MINIMUM NO. OF CASTS BETWEEN DRAINS	MAXIMUM NO. OF CASTS BETWEEN DRAINS	AVG NO. OF CASTS BETWEEN DPAINS	MINIMUM SLAG PER TON HOT METAL (LBS)	MAXIMUM SLAG PER TON HOT METAL (LBS)	AVG SLAG PER TON HOT METAL (LBS)
35	24	38,000	135,000	83,591	3	30	12	2	8	4	400	1,168	658

MINIMUM COKE PER TON HOT METAL (LBS)	MAXIMUM COKE PER TON HOT METAL (LBS)	AVG COKE PER TON HOT METAL (LBS)	MINIMUM SILICON CONTENT HOT METAL (%)	MAXIMUM SILICON CONTENT HOT METAL (%)	AVG SILICON CONTENT HOT METAL (%)	MINIMUM SULFUR CONTENT HOT METAL (%)	MAXIMUM SULFUR CONTENT HOT METAL (%)	AVG SULFUR CONTENT HOT METAL (%)	MINIMUM MANGAN. CONTENT HOT METAL (%)	MAXIMUM MANGAN. CONTENT HOT METAL (%)	AVG MANGAN. CONTENT HOT METAL (%)
937	1,757	1,254	0.90	3.50	1.27	0.017	1.750	0.044	9.14	1.69	0.72

MINIMUM SLAG BASICITY (B/A)	MAXIMUM SLAG BASICITY (B/A)	AVG SLAG BASICITY (B/A)	MINIMUM SULFUR CONTENT OF SLAG (%)	MAXIMUM SULFUR CONTENT OF SLAG (%)	AVG SULFUR CONTENT OF SLAG (%)	MINIMUM ORE IN METAL BURDEN (%)	MAXIMUM ORE IN METAL BURDEN (%)	AVG ORE IN METAL BURDEN (%)	MINIMUM SINTER IN METAL BURDEN (%)	MAXIMUM SINTER IN METAL BURDEN (%)	AVG SINTER IN METAL BURDEN (%)	MINIMUM SCRAP IN METAL BURDEN (%)
0.88	2.00	1.11	0.085	2.450	1.607	0.0	93.0	24.5	0.0	80.0	36.7	0.0

MAXIMUM SCRAP IN METAL BURDEN (%)	AVG SCRAP IN METAL BURDEN (%)	MINIMUM PELLETS IN METAL BURDEN (%)	MAXIMUM PELLETS IN METAL BURDEN (%)	AVG PELLETS IN METAL BURDEN (%)	MINIMUM HOT METAL TEMP (DEG F)	MAXIMUM HOT METAL TEMP (DEG F)	AVG HOT METAL TEMP (DEG F)	MINIMUM FREQ IRON RUNNER REMAKE (DAYS)	MAXIMUM FREQ IRON RUNNER REMAKE (DAYS)	AVG FREQ IRON RUNNER REMAKE (DAYS)	MINIMUM NO. OF CASTS BETWEEN RUNNER RELINE	MAXIMUM NO. OF CASTS BETWEEN RUNNER RELINE
17.0	4.9	0.0	100.0	56.5	2450	2850	2695	1.000	10.000	2.119	1	68

AVG NO. OF CASTS BETWEEN RUNNER RELINE	MINIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	AVG NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MINIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	AVG NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MINIMUM CAST HOUSE VOLUME (CU FT)	MAXIMUM CAST HOUSE VOLUME (CU FT)	AVG CAST HOUSE VOLUME (CU FT)	MEDIAN CAST HOUSE VOLUME (CU FT)
11	0	500	39	0	40	9	131,618	1,227,409	391,955	390,000

TABLE A-2
AVERAGES OF VALUES OBTAINED FROM QUESTIONNAIRE SURVEY OF STEEL MILLS
ENGLISH UNITS
CLASS 2

MINIMUM WORKING VOLUME (CU FT)	MAXIMUM WORKING VOLUME (CU FT)	AVG WORKING VOLUME (CU FT)	MINIMUM RECORD DAILY PROD HOT METAL (SHORT TONS)	MAXIMUM RECORD DAILY PROD HOT METAL (SHORT TONS)	AVG RECORD DAILY PROD HOT METAL (SHORT TONS)	MINIMUM CURRENT DAILY PROD HOT METAL (SHORT TONS)	MAXIMUM CURRENT DAILY PROD HOT METAL (SHORT TONS)	AVG CURRENT DAILY PROD HOT METAL (SHORT TONS)	MINIMUM NO. OF CASTS PER DAY	MAXIMUM NO. OF CASTS PER DAY
54,830	99,999	70,950	3,766	7,614	4,981	2,752	6,200	4,084	8	12

AVG NO. OF CASTS PER DAY	MINIMUM HEARTH DIAMETER (FEET)	MAXIMUM HEARTH DIAMETER (FEET)	AVG HEARTH DIAMETER (FEET)	MINIMUN IRON NOTCH BIT SZ. (IN)	MAXIMUN IRON NOTCH BIT SZ. (IN)	AVG IRON NOTCH BIT SZ. (IN)	MINIMUM NO. OF IRON NOTCHES	MAXIMUM NO. OF IRON NOTCHES	AVG NO. OF IRON NOTCHES	MINIMUM NO. OF CINDER NOTCHES	MAXIMUM NO. OF CINDER NOTCHES	AVG NO. OF CINDER NOTCHES	MINIMUM IRON TROUGH LENGTH (FEET)
9	25.50	40.00	32.50	1.88	4.00	2.94	2	3	2	0	2	1	18

MAXIMUM IRON TROUGH LENGTH (FEET)	AVG IRON TROUGH LENGTH (FEET)	MINIMUM IRON TROUGH WIDTH (IN.)	MAXIMUM IRON TROUGH WIDTH (IN.)	AVG IRON TROUGH WIDTH (IN.)	MINIMUM IRON TROUGH DEPTH (IN.)	MAXIMUM IRON TROUGH DEPTH (IN.)	AVG IRON TROUGH DEPTH (IN.)	MINIMUM DUR OF CAST (MIN)	MAXIMUM DUR OF CAST (MIN)	AVG DUR OF CAST (MIN)	MINIMUM DUR OF FLUSH (MIN)	MAXIMUM DUR OF FLUSH (MIN)	AVG DUR OF FLUSH (MIN)	MINIMUM BEGIN. BLAST PRESS (PSIG)
47	30	24	72	38	12	36	24	45	110	72			0	27

MAXIMUM BEGIN. BLAST PRESS (PSIG)	AVG BEGIN. BLAST PRESS (PSIG)	MINIMUM BEGIN. BLAST VOLUME (SCFM)	MAXIMUM BEGIN. BLAST VOLUME (SCFM)	AVG BEGIN. BLAST VOLUME (SCFM)	MINIMUM STOPPED BLAST PRESS (PSIG)	MAXIMUM STOPPED BLAST PRESS (PSIG)	AVG STOPPED BLAST PRESS (PSIG)	MINIMUM NO. OF CASTS BETWEEN DRAINS	MAXIMUM NO. OF CASTS BETWEEN DRAINS	AVG NO. OF CASTS BETWEEN DRAINS	MINIMUM SLAG PER TON HOT METAL (LBS)	MAXIMUM SLAG PER TON HOT METAL (LBS)	AVG SLAG PER TON HOT METAL (LBS)
49	33	120,000	245,000	161,672	13	49	26	2	30	11	423	700	591

MINIMUM COKE PER TON HOT METAL (LBS)	MAXIMUM COKE PER TON HOT METAL (LBS)	AVG COKE PER TON HOT METAL (LBS)	MINIMUM SILICON CONTENT HOT METAL (%)	MAXIMUM SILICON CONTENT HOT METAL (%)	AVG SILICON CONTENT HOT METAL (%)	MINIMUM SULFUR CONTENT HOT METAL (%)	MAXIMUM SULFUR CONTENT HOT METAL (%)	AVG SULFUR CONTENT HOT METAL (%)	MINIMUM MANGAN. CONTENT HOT METAL (%)	MAXIMUM MANGAN. CONTENT HOT METAL (%)	AVG MANGAN. CONTENT HOT METAL (%)
942	1,304	1,116	0.70	1.40	1.06	0.030	0.036	0.031	0.42	1.32	0.73

MINIMUM SLAG BASICITY (B/A)	MAXIMUM SLAG BASICITY (B/A)	AVG SLAG BASICITY (B/A)	MINIMUM SULFUR CONTENT OF SLAG (%)	MAXIMUM SULFUR CONTENT OF SLAG (%)	AVG SULFUR CONTENT OF SLAG (%)	MINIMUM ORE IN METAL BURDEN (%)	MAXIMUM ORE IN METAL BURDEN (%)	AVG ORE IN METAL BURDEN (%)	MINIMUM SINTER IN METAL BURDEN (%)	MAXIMUM SINTER IN METAL BURDEN (%)	AVG SINTER IN METAL BURDEN (%)	MINIMUM SCRAP IN METAL BURDEN (%)
0.98	1.20	1.11	1.100	1.030	1.486	2.0	74.0	20.0	6.0	50.0	27.9	2.0

MAXIMUM SCRAP IN METAL BURDEN (%)	AVG SCRAP IN METAL BURDEN (%)	MINIMUM PELLETS IN METAL BURDEN (%)	MAXIMUM PELLETS IN METAL BURDEN (%)	AVG PELLETS IN METAL BURDEN (%)	MINIMUM HOT METAL TEMP (DEG F)	MAXIMUM HOT METAL TEMP (DEG F)	AVG HOT METAL TEMP (DEG F)	MINIMUM FREQ IRON RUNNER REMAKE (DAYS)	MAXIMUM FREQ IRON RUNNER REMAKE (DAYS)	AVG FREQ IRON RUNNER REMAKE (DAYS)	MINIMUM NO. OF CASTS BETWEEN RUNNER RELINE	MAXIMUM NO. OF CASTS BETWEEN RUNNER RELINE
7.0	3.7	50.0	100.0	72.3	2650	2810	2735	1.000	5.000	2.182	3	30

AVG NO. OF CASTS BETWEEN RUNNER RELINE	MINIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	AVG NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MINIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	AVG NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MINIMUM CAST HOUSE VOLUME (CU FT)	MAXIMUM CAST HOUSE VOLUME (CU FT)	AVG CAST HOUSE VOLUME (CU FT)	MEDIAN CAST HOUSE VOLUME (CU FT)
12	3	93	23	1	30	9	260,000	1,491,259	795,038	790,000

TABLE A-3
AVERAGES OF VALUES OBTAINED FROM QUESTIONNAIRE SURVEY OF STEEL MILLS
SI UNITS
CLASS 1

MINIMUM WORKING VOLUME (CU MET)	MAXIMUM WORKING VOLUME (CU MET)	AVG WORKING VOLUME (CU MET)	MINIMUM RECORD DAILY PROD HOT METAL (KG)	MAXIMUM RECORD DAILY PROD HOT METAL (KG)	AVG RECORD DAILY PROD HOT METAL (KG)	MINIMUM CURRENT DAILY PROD HOT METAL (KG)	MAXIMUM CURRENT DAILY PROD HOT METAL (KG)	AVG CURRENT DAILY PROD HOT METAL (KG)	MINIMUM NO. OF CASTS PER DAY	MAXIMUM NO. OF CASTS PER DAY
462	1,671	1,148	.958895E+06	.389545E+07	.221010E+07	.000000E+01	.294835E+07	.163454E+07	0	9

AVG NO. OF CASTS PER DAY	MINIMUM HEARTH DIAMETER (METERS)	MAXIMUM HEARTH DIAMETER (METERS)	AVG HEARTH DIAMETER (METERS)	MINIMUM IRON NOTCH BIT SZ. (MM)	MAXIMUM IRON NOTCH BIT SZ. (MM)	AVG IRON NOTCH BIT SZ. (MM)	MINIMUM NO. OF IRON NOTCHES	MAXIMUM NO. OF IRON NOTCHES	AVG NO. OF IRON NOTCHES	MINIMUM NO. OF CINDER NOTCHES	MAXIMUM NO. OF CINDER NOTCHES	AVG NO. OF CINDER NOTCHES	MINIMUM IRON TROUGH LENGTH (METERS)
7	4.609	9.449	7.715	57.15	101.60	81.86	1	1	1	0	2	1	2.44

MAXIMUM IRON TROUGH LENGTH (METERS)	AVG IRON TROUGH LENGTH (METERS)	MINIMUM IRON TROUGH WIDTH (MM)	MAXIMUM IRON TROUGH WIDTH (MM)	AVG IRON TROUGH WIDTH (MM)	MINIMUM IRON TROUGH DEPTH (MM)	MAXIMUM IRON TROUGH DEPTH (MM)	AVG IRON TROUGH DEPTH (MM)	MINIMUM DUR OF CAST (MIN)	MAXIMUM DUR OF CAST (MIN)	AVG DUR OF CAST (MIN)	MINIMUM DUR OF FLUSH (MIN)	MAXIMUM DUR OF FLUSH (MIN)	AVG DUR OF FLUSH (MIN)
9.75	6.82	152.40	1828.80	1070.69	50.80	1524.00	678.20	25	90	46	12	180	40

MINIMUM BEGINNING BLAST PRESSURE (PASCALS)	MAXIMUM BEGINNING BLAST PRESSURE (PASCALS)	AVG BEGINNING BLAST PRESSURE (PASCALS)	MINIMUM BEGINNING BLAST VOLUME (CU MET/SEC)	MAXIMUM BEGINNING BLAST VOLUME (CU MET/SEC)	AVG BEGINNING BLAST VOLUME (CU MET/SEC)	MINIMUM STOPPED BLAST PRESSURE (PASCALS)	MAXIMUM STOPPED BLAST PRESSURE (PASCALS)	AVG STOPPED BLAST PRESSURE (PASCALS)
.103421E+06	.241316E+06	.166881E+06	.179340E+02	.637128E+02	.394505E+02	.206843E+05	.206843E+06	.833909E+05

MINIMUM NO. OF CASTS BETWEEN DRAINS	MAXIMUM NO. OF CASTS BETWEEN DRAINS	AVG NO. OF CASTS BETWEEN DRAINS	MINIMUM SLAG PER TON HOT METAL (KGS)	MAXIMUM SLAG PER TON HOT METAL (KGS)	AVG SLAG PER TON HOT METAL (KGS)	MINIMUM COKE PER TON HOT METAL (KGS)	MAXIMUM COKE PER TON HOT METAL (KGS)	AVG COKE PER TON HOT METAL (KGS)	MINIMUM SILICON CONTENT HOT METAL (%)	MAXIMUM SILICON CONTENT HOT METAL (%)	AVG SILICON CONTENT HOT METAL (%)
2	8	4	181	529	302	425	796	568	0.90	3.50	1.27

MINIMUM SULFUR CONTENT HOT METAL (%)	MAXIMUM SULFUR CONTENT HOT METAL (%)	AVG SULFUR CONTENT HOT METAL (%)	MINIMUM MANGAN. CONTENT HOT METAL (%)	MAXIMUM MANGAN. CONTENT HOT METAL (%)	AVG MANGAN. CONTENT HOT METAL (%)	MINIMUM SLAG BASICITY (B/A)	MAXIMUM SLAG BASICITY (B/A)	AVG SLAG BASICITY (B/A)	MINIMUM SULFUR CONTENT OF SLAG (%)	MAXIMUM SULFUR CONTENT OF SLAG (%)	AVG SULFUR CONTENT OF SLAG (%)	MINIMUM ORE IN METAL BURDEN (%)
0.027	1.750	0.044	0.14	1.69	0.72	0.88	2.00	1.11	0.085	2.450	1.607	0.0

MAXIMUM ORE IN METAL BURDEN (%)	AVG ORE IN METAL BURDEN (%)	MINIMUM SINTER IN METAL BURDEN (%)	MAXIMUM SINTER IN METAL BURDEN (%)	AVG SINTER IN METAL BURDEN (%)	MINIMUM SCRAP IN METAL BURDEN (%)	MAXIMUM SCRAP IN METAL BURDEN (%)	AVG SCRAP IN METAL BURDEN (%)	MINIMUM PELLETS IN METAL BURDEN (%)	MAXIMUM PELLETS IN METAL BURDEN (%)	AVG PELLETS IN METAL BURDEN (%)	MINIMUM HOT METAL TEMP (DEG C)	MAXIMUM HOT METAL TEMP (DEG C)
93.0	24.5	0.0	80.0	36.7	0.0	17.0	4.9	8.0	100.0	56.5	1,343	1,565

AVG HOT METAL TEMP (DEG C)	MINIMUM FREQ IRON RUNNER REMAKE (DAYS)	MAXIMUM FREQ IRON RUNNER REMAKE (DAYS)	AVG FREQ IRON RUNNER REMAKE (DAYS)	MINIMUM NO. OF CASTS BETWEEN RUNNER RELINE	MAXIMUM NO. OF CASTS BETWEEN RUNNER RELINE	AVG NO. OF CASTS BETWEEN RUNNER RELINE	MINIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	AVG NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MINIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	AVG NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MINIMUM CAST HOUSE VOLUME (CU MET)	MAXIMUM CAST HOUSE VOLUME (CU MET)	AVG CAST HOUSE VOLUME (CU MET)	MEDIAN CAST HOUSE VOLUME (CU-MET)
1,479	1.000	10.000	2.119	1	60	11	0	500	39	0	48	9	3,727	34,756	11,893	11,042

TABLE A-4
AVERAGES OF VALUES OBTAINED FROM QUESTIONNAIRE SURVEY OF STEEL MILLS
SI UNITS
CLASS 2

MINIMUM WORKING VOLUME (CU MET)	MAXIMUM WORKING VOLUME (CU MET)	AVG WORKING VOLUME (CU MET)	MINIMUM RECORD DAILY PROD HOT METAL (KG)	MAXIMUM RECORD DAILY PROD HOT METAL (KG)	AVG RECORD DAILY PROD HOT METAL (KG)	MINIMUM CURRENT DAILY PROD HOT METAL (KG)	MAXIMUM CURRENT DAILY PROD HOT METAL (KG)	AVG CURRENT DAILY PROD HOT METAL (KG)	MINIMUM NO. OF CASTS PER DAY	MAXIMUM NO. OF CASTS PER DAY
1,552	2,831	2,008	.341646E+07	.690731E+07	.451943E+07	.249657E+07	.562455E+07	.370527E+07	8	12

AVG NO. OF CASTS PER DAY	MINIMUM HEARTH DIAMETER (METERS)	MAXIMUM HEARTH DIAMETER (METERS)	AVG HEARTH DIAMETER (METERS)	MINIMUM IRON NOTCH BIT SZ. (MM)	MAXIMUM IRON NOTCH BIT SZ. (MM)	AVG IRON NOTCH BIT SZ. (MM)	MINIMUM NO. OF IRON NOTCHES	MAXIMUM NO. OF IRON NOTCHES	AVG NO. OF IRON NOTCHES	MINIMUM NO. OF CINDER NOTCHES	MAXIMUM NO. OF CINDER NOTCHES	AVG NO. OF CINDER NOTCHES	MINIMUM IRON TROUGH LENGTH (METERS)
9	7.772	12.192	9.907	47.75	101.60	74.77	2	3	2	0	2	1	5.49

MAXIMUM IRON TROUGH LENGTH (METERS)	AVG IRON TROUGH LENGTH (METERS)	MINIMUM IRON TROUGH WIDTH (MM)	MAXIMUM IRON TROUGH WIDTH (MM)	AVG IRON TROUGH WIDTH (MM)	MINIMUM IRON TROUGH DEPTH (MM)	MAXIMUM IRON TROUGH DEPTH (MM)	AVG IRON TROUGH DEPTH (MM)	MINIMUM DUR OF CAST (MIN)	MAXIMUM DUR OF CAST (MIN)	AVG DUR OF CAST (MIN)	MINIMUM DUR OF FLUSH (MIN)	MAXIMUM DUR OF FLUSH (MIN)	AVG DUR OF FLUSH (MIN)
14.33	9.37	609.60	1828.80	969.82	304.80	914.40	630.38	45	110	72			0

MINIMUM BEGINNING BLAST PRESSURE (PASCALS)	MAXIMUM BEGINNING BLAST PRESSURE (PASCALS)	AVG BEGINNING BLAST PRESSURE (PASCALS)	MINIMUM BEGINNING BLAST VOLUME (CU MET/SEC)	MAXIMUM BEGINNING BLAST VOLUME (CU MET/SEC)	AVG BEGINNING BLAST VOLUME (CU MET/SEC)	MINIMUM STOPPED BLAST PRESSURE (PASCALS)	MAXIMUM STOPPED BLAST PRESSURE (PASCALS)	AVG STOPPED BLAST PRESSURE (PASCALS)
.156157E+06	.337843E+06	.232541E+06	.566336E+02	.115627E+03	.763009E+02	.896318E+05	.337843E+06	.182397E+06

MINIMUM NO. OF CASTS BETWEEN DRAINS	MAXIMUM NO. OF CASTS BETWEEN DRAINS	AVG NO. OF CASTS BETWEEN DRAINS	MINIMUM SLAG PER TON HOT METAL (KGS)	MAXIMUM SLAG PER TON HOT METAL (KGS)	AVG SLAG PER TON HOT METAL (KGS)	MINIMUM COKE PER TON HOT METAL (KGS)	MAXIMUM COKE PER TON HOT METAL (KGS)	AVG COKE PER TON HOT METAL (KGS)	MINIMUM SILICON CONTENT HOT METAL (%)	MAXIMUM SILICON CONTENT HOT METAL (%)	AVG SILICON CONTENT HOT METAL (%)
2	30	11	191	317	267	427	591	505	0.70	1.40	1.06

MINIMUM SULFUR CONTENT HOT METAL (%)	MAXIMUM SULFUR CONTENT HOT METAL (%)	AVG SULFUR CONTENT HOT METAL (%)	MINIMUM MANGAN. CONTENT HOT METAL (%)	MAXIMUM MANGAN. CONTENT HOT METAL (%)	AVG MANGAN. CONTENT HOT METAL (%)	MINIMUM SLAG BASICITY (B/A)	MAXIMUM SLAG BASICITY (B/A)	AVG SLAG BASICITY (B/A)	MINIMUM SULFUR CONTENT OF SLAG (%)	MAXIMUM SULFUR CONTENT OF SLAG (%)	AVG SULFUR CONTENT OF SLAG (%)	MINIMUM ORE IN METAL BURDEN (%)
0.030	0.036	0.031	0.42	1.32	0.78	0.98	1.20	1.11	1.100	1.830	1.486	2.0

MAXIMUM ORE IN METAL BURDEN (%)	AVG ORE IN METAL BURDEN (%)	MINIMUM SINTER IN METAL BURDEN (%)	MAXIMUM SINTER IN METAL BURDEN (%)	AVG SINTER IN METAL BURDEN (%)	MINIMUM SCRAP IN METAL BURDEN (%)	MAXIMUM SCRAP IN METAL BURDEN (%)	AVG SCRAP IN METAL BURDEN (%)	MINIMUM PELLETS IN METAL BURDEN (%)	MAXIMUM PELLETS IN METAL BURDEN (%)	AVG PELLETS IN METAL BURDEN (%)	MINIMUM HOT METAL TEMP (DEG C)	MAXIMUM HOT METAL TEMP (DEG C)
74.0	20.0	6.0	50.0	27.9	2.0	7.0	3.7	50.0	100.0	72.3	1,454	1,543

AVG HOT METAL TEMP (DEG C)	MINIMUM FREQ IRON RUNNER REMAKE (DAYS)	MAXIMUM FREQ IRON RUNNER REMAKE (DAYS)	AVG FREQ IRON RUNNER REMAKE (DAYS)	MINIMUM NO. OF CASTS BETWEEN RUNNER RELINE	MAXIMUM NO. OF CASTS BETWEEN RUNNER RELINE	AVG NO. OF CASTS BETWEEN RUNNER RELINE	MINIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	AVG NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	MINIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MAXIMUM NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	AVG NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	MINIMUM CAST HOUSE VOLUME (CU MET)	MAXIMUM CAST HOUSE VOLUME (CU MET)	AVG CAST HOUSE VOLUME (CU MET)	MEDIAN CAST HOUSE VOLUME (CU-MET)
1,501	1.000	5.000	2.182	3	30	12	3	90	23	1	30	9	7,508	42,227	22,512	22,368

TABLE A-5
VALUES OBTAINED FROM QUESTIONNAIRE TRANSMITTED TO STEEL MILLS BY AISI

EPA BLAST FURNACE CAST HOUSE INVENTORY
BETZ ENVIRONMENTAL ENGINEERS
FEBRUARY 21,1977
ENGLISH-UNITS

BLAST FURNACE CODE	WORKING VOLUME (CU FT)	RECORD DAILY PROD HOT METAL (SHORT TONS)	CURRENT DAILY PROD HOT METAL (SHORT TONS)	NO. OF CASTS PER DAY	HEARTH DIAMETER (FEET)	IRON NOTCH BIT SIZE (IN)	NO. OF IRON NOTCHES	NO. OF CINDER NOTCHES	IRON TROUGH LENGTH (FEET)	IRON TROUGH WIDTH (IN.)	IRON TROUGH DEPTH (IN.)
0998	22,750		1,000	6	18.00		1	1			
0999	22,750		1,000	6	19.50		1	1			
1001	55,324	4,016	3,734	10	25.50	4.00	2	2	28	36	30
1002	23,686	1,620	1,241	7	18.50	3.50	1	1	22	48	25
1003	30,526	1,798			19.50	3.50	1	2	21	48	25
1101	72,000	4,436	3,540	10	33.50	3.50	2	1	31	36	24
1102	52,538	3,652	2,047	7	28.75	3.50	1	2	24	36	17
1201	50,300	3,098		6	27.25	3.50	1	1	32	39	30
1301	54,431	3,864	2,835	8	30.00	3.50	1	1	19	48	24
1302	49,748	3,359	2,062	8	28.00	3.50	1	1	19	48	24
1303	54,834	3,800	2,643	8	30.00	3.50	1	1	19	48	24
1304	39,739	2,667	1,767	8	24.00	3.50	1	1	19	48	24
1401	38,395	2,156	1,650	7	25.50	3.50	1	2	30	36	20
1402	38,887	2,201	1,650	7	25.50	3.50	1	2	24	36	20
1403	42,245	2,760	2,382	8	28.00	3.50	1	2	30	36	20
1404	42,853	2,525	2,112	7	28.00	3.50	1	2	24	36	20
1405	24,892	1,395	900	5	19.75	3.50	1	1	20	36	20
1406	24,998	1,373	900	5	19.75	3.50	1	1	20	36	20
1407	47,167	2,490		7	28.00	3.50	1	2	22	36	20
1408	54,515	3,514	2,674	8	30.00	3.50	1	2	28	36	20
1409	54,830	4,772	3,001	8	30.00	3.50	2	2	30	36	20
1410	54,799	3,802	2,800	8	30.00	3.50	1	2	30	36	20
1503	51,044	3,420	2,215	8	29.50	3.50	1	1	25	60	48
1504	39,477	2,666	1,656	8	26.00	3.50	1	1	29	60	48
1505	39,998	2,666	2,008	8	27.00	3.50	1	2	20	24	48
1506	50,885	3,022	2,269	8	29.00	4.00	1	1	25	60	48
1507	55,112	3,726	2,592	8	30.00	4.00	1	2	25	60	48
1602	33,327	1,718	1,615	8	26.00	3.00	1	2	17	30	24
1603	47,578	2,800	2,457	8	26.00	3.00	1	2	25	30	20
1604	48,568	2,727	2,503	8	28.00	3.00	1	2	25	30	22
1701	89,234	5,819	5,115	9	38.25	2.25	2	1	27	24	24
1702	86,646	5,739	5,739	10	35.00	2.25	2	1	27	24	24
1804	32,100	1,210	800	6	22.75	3.00	1	1	29	34	21
1805	30,683	1,057	800	6	21.00	3.00	1	1	29	34	21
1806	24,656	1,101	800	6	21.30	3.00	1	1	29	34	21
1807	31,310	1,324	800	6	21.75	3.00	1	1	22	27	17
2002	54,428	2,550	1,457	5	29.25	3.25	1	2	21	66	24
2101	28,058	2,082	1,710	8	20.00	3.50	1	1	26	28	15
2102	27,509	2,164	1,760	8	20.00	3.50	1	1	26	28	15
2103	54,987	3,821	3,110	8	29.00	3.50	1	2	25	30	15
2201	30,928	2,146	1,660	8	20.80	3.00	1	2	21	45	22
2202	25,689	2,105	1,744	8	20.00	3.00	1	2	21	42	27
2203	31,946	2,327	1,830	8	22.00	3.00	1	2	21	48	28
2204	28,573	2,309	1,749	8	21.00	3.00	1	2	16	60	27
2205	46,323	3,273	2,549	8	27.00	3.00	1	2	21	52	26
2206	47,142	3,239	2,240	8	26.50	3.00	1	2	21	52	26

EPA BLAST FURNACE CAST HOUSE INVENTORY
BETZ ENVIRONMENTAL ENGINEERS
FEBRUARY 21,1977
ENGLISH-UNITS

BLAST FURNACE CODE	WORKING VOLUME (CU FT)	RECORD DAILY PROD HOT METAL (SHORT TONS)	CURRENT DAILY PROD HOT METAL (SHORT TONS)	NO. OF CASTS PER DAY	HEARTH DIAMETER (FEET)	IRON NOTCH BIT SIZE (IN)	NO. OF IRON NOTCHES	NO. OF CINDER NOTCHES	IRON TROUGH LENGTH (FEET)	IRON TROUGH WIDTH (IN.)	IRON TROUGH DEPTH (IN.)
2207	46,954	3,488	2,560	8	26.50	3.00	1	2	29	53	26
2208	46,595	3,488	2,558	8	26.50	3.00	1	2	29	53	26
2301	41,448	2,469	1,925	8	25.25	3.50	1	0	28	48	19
2302	27,027	1,622	1,050	8	19.66	3.50	1	0	24	39	19
2303	25,584				19.00		1	1	20	26	18
2304	28,204	1,538	950	8	21.00	3.50	1	1	25	40	15
2501	54,400	2,304	2,291	8	29.00	3.20	1	1	30	72	48
2502	43,892	2,806	0	8	28.50	3.50	1	2	28	48	24
2503	54,000	4,025	3,250	8	29.00	3.30	1	1	31	72	24
2504	34,100	2,181	1,600	8	28.50	3.50	1	1	22	48	18
2505	54,400	3,069	0	0	29.00		1	1	26	6	2
2506	31,500	2,030	1,500	8	27.30	3.50	1	1	24	48	18
2512	47,188	3,050	2,310	8	27.50	3.00	1	1	18	50	19
2514	57,378	3,891	2,752	9	30.50	3.00	2	0	24	48	12
2601	39,734	2,218	1,843	6	27.00	2.50	1	1	24	30	26
2602	39,734	2,372	1,857	6	27.00	2.50	1	1	24	30	26
2603	39,734	2,132	1,825	6	27.00	2.50	1	1	32	48	26
2604	51,212	2,983	2,304	6	29.50	2.50	1	1	24	30	26
2701	52,810	2,648	1,800	9	27.30	3.50	1	2	18	48	14
2801	57.238	3,449	2,700	8	28.50	4.00	1	2	25	48	30
2802	57,238	3,561	2,650	8	28.50	4.00	1	2	25	48	30
2901	50,652	2,419	2,306	8	27.30	3.50	1	2	19	48	36
2902	50,490	2,453	2,500	8	27.30	3.50	1	2	21	48	30
2907	56.197	2,779	2,200	8	27.00	3.50	1	1	18	24	30
2908	45,960	2,789	2,100	8	27.00	3.50	1	1	25	24	30
2909	46,685	2,777	2,100	8	26.25	3.50	1	1	19	24	30
2910	46,670	2,893	2,100	8	26.25	3.50	1	1	18	24	30
2911	16,339		700	5	16.25	2.75	1	1	12	45	18
2912	16,811		775	5	15.12	2.75	1	1	10	36	18
2913	29,243		1,000	6	20.00	2.75	1	1	8	54	18
3001	53,163	3,023	2,600	6	28.00	3.25	1	1	24	20	32
3002	42.733	2,213	2,048	6	26.25	2.50	1	1	16	60	60
3003	46.530	2,175	2,000	6	26.25	2.50	1	1	20	60	60
3008	44,870	2,331	2,090	6	27.00	2.75	1	2	22	38	22
3009	43,271	2,083	1,833	6	27.00	3.00	1	2	22	40	23
3010	56.143	2,709	1,751	6	29.50	2.75	1	2	25	57	22
3011	56.140	2.756	2,115	6	29.50	2.75	1	2	25	56	23
3014	27,751	1,550		6	21.50	2.50	1	1	24	26	18
3015	35,213	1,995	1,743	6	22.75	2.50	1	1	25	46	22
3016	54,400	2.776	2,600	7	28.00	3.00	1	1	24	60	30
3017	19,718	1,057	850	7	17.00	3.00	1	1	19	52	24
3018	45,606	2,003	1,812	6	26.00	3.00	1	2	21	58	24
3201	31,602	1,609	1,200	6	22.00	3.50	1	1	20	36	30
3301	58,507	4,294	2,850	9	29.50	3.25	1	1	30	36	30
3302	59.035	3,771	2,850	9	31.00	3.25	1	1	30	36	30
3303	59,035	4,157	2,850	9	31.00	3.25	1	1	30	36	30

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BLAST FURNACE CODE	WORKING VOLUME (CU FT)	RECORD DAILY PROD HOT METAL (SHORT TONS)	CURRENT DAILY PROD HOT METAL (SHORT TONS)	NO. OF CASTS PER DAY	HEARTH DIAMETER (FEET)	IRON NOTCH BIT SIZE (IN)	NO. OF IRON NOTCHES	NO. OF CINDER NOTCHES	IRON TROUGH LENGTH (FEET)	IRON TROUGH WIDTH (IN.)	IRON TROUGH DEPTH (IN.)
3304	48,986	3,030	1,400	8	29.00	3.00	1	2	16	36	32
3305	48,986	3,240	2,400	9	29.00	2.50	1	1	16	36	32
3306	38,837	2,321	1,937	8	26.00	2.50	1	1	16	48	32
3308	31,980	1,778	1,400	8	25.00	3.00	1	1	16	36	32
3309	32,510	1,545	1,100	8	23.50	3.00	1	1	18	36	32
3310	51,281	2,999	2,350	7	29.50	3.00	1	2	23	66	38
3311	51,281	2,814	2,250	7	29.50	3.00	1	2	17	48	36
3312	31,558	1,982	910	6	23.50	3.00	1	2	19	45	25
3313	31,558	1,560	1,037	6	23.50	3.00	1	2	24	50	34
3315	25,821	1,611		6	20.00	3.00	1	1	12	36	18
3316	32,541	1,992	1,200	8	23.00	3.00	1	1	12	36	18
3317	35,215	2,547	1,600	9	24.50	3.00	1	1	12	35	18
3318	58,045	3,953	2,800	11	28.00	3.00	2	2	18	48	24
3320	37,724	2,087	1,707	7	25.00	3.00	1	1	18	48	30
3321	34,724	2,107	1,749	7	23.50	3.00	1	1	17	48	30
3322	33,710	1,832		7	23.00	3.00	1	1	17	38	30
3323	37,356	1,922	1,143	7	25.00	3.00	1	1	17	48	30
3324	24,929		1,000	7	20.50	3.25	1	1	22	33	21
3325	47,563	3,151	2,620	8	28.25	3.25	1	2	23	42	23
3326	27,326				20.50	3.25	1	1	19	33	21
3327	47,550	3,066	1,900	8	28.00	3.25	1	2	29	42	21
3328	42,106		1,350		28.00	3.25	1	1	31	42	23
3329	41,017		1,990	8	26.50	3.25	1	2	23	42	27
3330	28,827		1,000	6	23.00	3.25	1	1	22	33	21
3331	42,680		2,160	8	27.00	3.25	1	1	22	42	26
3332	39,256		1,250	7	25.00	3.25	1	1	22	33	21
3333	39,256		1,400	7	25.00	3.25	1	1	22	33	21
3334	99,999	7,614	6,200	12	40.00	1.88	3	0	47	24	16
3335	31,237	1,596	1,100	7	24.00	2.25	1	1	19	54	48
3336	68,538	3,766	3,286	10	32.00	3.00	2	1	41	42	31
3337	36,232	1,672	1,665	7	25.30	3.00	1	1	30	30	25
3338	51,004	2,573	2,409	7	29.00	3.00	1	1	31	40	28
3344	43,666	2,259	1,874	6	26.50	4.00	1	2	21	27	32
3345	43,666	2,224	2,076	6	26.50	4.00	1	2	21	27	32
3346	43,666	2,242			26.50	4.00	1	2			
3347	31,164	1,256	850	5	22.00	3.30	1	1	26	36	36
3348	33,235	1,300	900	5	22.50	3.30	1	1	26	36	36
3349	31,865	1,154	925		21.50	3.30	1	1	23	36	36
3350	40,829	1,570	1,300	5	25.00	3.30	1	1	25	48	48
3351	40,995	1,710	1,400	5	25.00	3.30	1	1	25	48	48
3352	52,070	2,407	1,900	5	28.70	3.30	1	1	26	72	60
3356	42,140	1,854	1,100	6	26.00	3.25	1	2	24	48	21
3357	28,635	1,784		9	23.00	3.25	1	1	18	60	27
3358	28,900	1,816	1,500	9	23.25	3.25	1	1	23	60	29
3359	48,488	3,521	2,800	9	28.50	3.25	1	1	23	62	30
3360	48,914	3,179	2,300	9	29.00	3.25	1	1	17	60	24

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3361	29,444	1,780		9	23.50	3.25	1	1	16	60	27
3409	30,771	1,327		6	22.50	3.50	1	1	18	26	18
3410	30,561	1,450		6	22.00	3.50	1	1	18	26	18
3411	43,188	1,586	1,308	6	24.50	3.50	1	1	20	26	20
3412	41,113	1,828	1,782	8	23.80	3.50	1	1	20	28	20
3413	48,191	2,405		7	27.50	3.50	1	2	28	30	24
3414	29,422	1,618		7	22.80	3.50	1	2	27	24	24
3415	55,996	3,132	2,518	6	29.50	3.00	1	1	23	30	30
3416	64,000	4,165	4,116	9	32.80	3.00	2	1	35	30	36
3501	23,844	1,892	1,377	8	19.00	3.50	1	1	16	33	15
3502	37,770	2,843	2,392	8	25.00	3.50	1	1	18	60	22
3503	52,866	3,774	2,966	8	29.00	3.50	1	1	22	72	32
3504	74,491	6,629	4,645	10	32.00	3.00	2	1	30	72	32

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BLAST FURNACE CODE	DUR OF CAST (MIN)	O2 USED TO OPEN TAP?	FLUSH AT CINDER NOTCH?	DUR OF FLUSH (MIN)	BEGIN. BLAST PRESS (PSIG)	BEGIN. BLAST VOLUME (SCFM)	STOPPED BLAST PRESS (PSIG)	TROUGH NORMALLY DRAINED AFTER CAST?	NO. OF CASTS BETWEEN DRAINS	SLAG PER TON HOT METAL (LBS)	COKE PER TON HOT METAL (LBS)
0998	30	YES	NO		18	50,000	10			500	1,300
0999	30	YES	NO		18	50,000	10			500	1,330
1001	45	YES	NO		30	140,000	20	YES		600	1,150
1002	25	OCCAS.	YES	12	22	49,000	14	YES		692	1,248
1003								YES			
1101	50	NO	NO		28	146,000	22	NO	3	661	1,074
1102	45	NO	YES	20	21	108,000	15	YES		715	1,177
1201	55	NO	NO		26	95,000	24	YES		602	1,148
1301	45	NO	NO		27	120,000	8	YES		590	1,140
1302	45	NO	NO		27	110,000	8	YES		580	1,190
1303	45	NO	NO		27	120,000	8	YES		570	1,179
1304	45	NO	NO		27	100,000	8	YES		615	1,193
1401	45	OCCAS.	NO		20	75,000	10	YES		755	1,600
1402	45	OCCAS.	NO		20	75,000	10	YES		780	1,580
1403	50	OCCAS.	NO		22	100,000	10	YES		600	1,120
1404	40	OCCAS.	NO		18	90,000	10	YES		600	1,140
1405	30	OCCAS.	YES	25	16	55,000	4	YES		749	1,670
1406	30	OCCAS.	YES	25	16	55,000	4	YES		740	1,520
1407	45	OCCAS.	NO		18	85,000	10	YES		750	1,600
1408	55	OCCAS.	NO		24	109,000	10	YES		560	1,160
1409	60	OCCAS.	NO		27	130,000	27	YES		540	1,260
1410	55	OCCAS.	NO		25	110,002	10	YES		715	1,276
1503	45	NO	NO		25	112,000	25	YES		920	1,121
1504	35	NO	NO		22	105,000	22	YES		900	1,559
1505	35	NO	NO		22	105,000	22	YES		900	1,197
1506	45	NO	NO		25	110,000	25	YES		900	1,326
1507	45	NO	NO		30	120,000	30	YES		930	1,315
1602	45	YES	NO		20	68,900	5	YES		584	1,248
1603	45	YES	NO		22	109,800	5	YES		574	1,110
1604	45	YES	NO		24	104,200	5	YES		570	1,150
1701	103	OCCAS.	NO		32	185,500	32	NO	2	543	951
1702	93	OCCAS.	NO		38	190,900	38	NO	2	572	942
1804	40	OCCAS.	YES	30	23	45,000	6	YES		1,000	1,340
1805	40	OCCAS.	YES	30	23	45,000	6	YES		1,000	1,340
1806	40	OCCAS.	YES	30	23	42,000	6	YES		1,000	1,340
1807	40	OCCAS.	YES	30	23	42,000	6	YES		1,000	1,340
2002	45	NO	NO		20	59,000	19	YES		570	1,248
2101	25	YES	NO		30	70,000	12	YES		450	1,151
2102	25	YES	NO		30	70,000	12	YES		425	1,144
2103	40	YES	NO		30	120,000	15	YES		476	1,077
2201	45	NO	YES	30	28	60,000	15	YES		593	1,140
2202	45	NO	YES	30	28	60,000	15	YES		648	1,122
2203	45	NO	YES	30	29	70,000	15	YES		511	1,031
2204	45	NO	YES	30	29	70,000	15	YES		601	1,101
2205	65	NO	YES	45	30	105,000	15	YES		536	997
2206	65	NO	YES	45	28	85,000	15	YES		606	946

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2207	55	NO	YES	45	30	100,000	15	YES		564	937
2208	45	NO	YES	45	30	100,000	15	YES		585	999
2301	30	YES			27	85,000	12	YES		550	1,120
23 2	30	YES	NO		25	55,000	12	YES		525	1,170
2303											
2304	30	OCCAS.	NO		22	56,000	15	YES		400	1,200
2501	45	YES	NO		25	105,000	12	YES		782	1,350
2502	60	OCCAS.	NO		18	98,000	10	YES		687	1,225
2503	45	OCCAS.	NO		35	135,000	19	YES	2	575	1,120
2504	40	OCCAS.	NO		18	85,000	6	YES		790	1,440
2505	60	OCCAS.	NO		25	105,000	10	YES		630	1,265
2506	45	OCCAS.	NO		17	75,000	10	YES		720	1,350
2512	45	YES	NO		27	95,000	22	YES		600	1,050
2514	45	YES	NO		28	120,000	22	YES		600	1,200
2601	55	OCCAS.	YES	40	25	75,000	10	YES		625	1,075
2602	55	OCCAS.	NO	40	25	75,000	10	YES		625	1,075
2603	55	OCCAS.	YES	40	25	75,000	10	YES		625	1,075
2604	65	OCCAS.	YES	45	30	90,000	10	YES		625	1,075
2701	45	OCCAS.	NO		25	80,000	16	YES		900	1,238
2801	50	NO	NO		23	110,003	23	NO	8	690	1,225
2802	50	NO	NO		23	110,000	23	NO	8	700	1,225
2901	45	OCCAS.	NO		28	95,000	10	YES		600	1,150
2902	45	OCCAS.	NO		30	100,000	10	YES		600	1,150
2907	45	YES	NO		25	96,000	5	YES		600	1,130
2908	45	YES	NO		25	85,000	5	YES		600	1,150
2909	45	YES	NO		25	85,000	5	YES		600	1,100
2910	45	YES	NO		25	85,000	5	YES		600	1,025
2911	25	YES	YES	15	16	39,000	5	YES		820	1,550
2912	25	YES	YES	15	18	38,000	5	YES		840	1,600
2913	25	YES	YES	15	22	58,000	5	YES		925	1,550
3001	60	NO	YES	75	30	124,000	5	YES		756	1,322
3002	50	YES	YES	20	24	95,000	10	YES		803	1,358
3003	50	YES	YES	20	24	90,000	10	YES		664	1,525
3008	51	YES	YES	75	30	115,000	5	YES		805	1,487
3009	60	YES	YES	75	24	95,000	5	YES		753	1,328
3010	60	YES	YES	75	30	115,000	5	YES		808	1,385
3011	60	YES	YES	75	27	115,003	5	YES		837	1,460
3014	60	YES	NO		18	55,000	7	YES			
3015	60	YES	NO		25	[illegible]	7	YES		570	1,181
3016	60	OCCAS.	NO		33	120,000	12	YES		600	1,130
3017	55	YES	NO		28	60,000	5	YES		916	1,503
3018	90	YES	NO		33	100,000	5	YES		792	1,483
3201	30	NO	YES	20	19	58,000	6	YES		600	1,180
3301	40	NO	NO		27	105,000	27	YES		550	1,060
3302	40	NO	NO		27	105,000	27	YES		550	1,062
3303	40	NO	NO		27	105,020	27	YES		550	1,060

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3304	40	NO	NO		30	100,000	10	YES		682	1,250
3305	30	NO	NO		34	108,000	10	NO	3	662	1,200
3306	40	NO	NO		29	100,000	10	NO	3	661	1,182
3308	40	NO	NO		20	80,000	10	YES		664	1,195
3309	40	NO	NO		18	70,000	9	YES		732	1,363
3310	45	OCCAS.	YES	60	30	115,000	24	YES		650	1,315
3311	45	OCCAS.	YES	60	33	103,000	25	YES		630	1,240
3312	40	OCCAS.	YES	60	24	64,000	22	YES		670	1,320
3313	40	OCCAS.	YES	60	26	61,000	23	YES		775	1,185
3315	45	OCCAS.	YES	60	16	55,000	15	YES		700	1,500
3316	45	OCCAS.	YES	30	20	75,000	15	YES		700	1,300
3317	45	OCCAS.	YES	30	25	90,000	20	YES		700	1,420
3318	45	OCCAS.			28	130,000	15	NO	11	700	1,192
3320	50	NO	NO	35	27	85,000	18	YES		670	1,158
3321	50	NO	NO	35	27	85,000	18	YES		734	1,230
3322	50	NO	NO	35	26	72,000	12	YES			
3323	50	NO	NO	35	28	72,000	18	YES		698	1,410
3324	40	YES	NO		16	57,000	14	YES		563	1,263
3325	40	YES	NO		26	105,000	24	YES		458	1,065
3326	40	YES	NO		15	55,000	14	YES		703	1,177
3327	40	YES	NO		22	88,000	20	YES		552	1,420
3328	40	YES	NO		21	77,000	19	YES			
3329	40	YES	NO		22	87,000	20	YES		528	1,154
3330	40	YES	NO		15	65,000	14	YES		780	1,333
3331	40	YES	NO		21	87,000	19	YES		560	1,282
3332	40	YES	NO		16	80,000	14	YES		600	1,272
3333	40	YES	NO		17	77,000	15	YES		620	1,260
3334	110	OCCAS.	NO		49	245,000	49	NO	30	525	1,190
3335	35	YES	YES	20	18	60,000	7	YES		1,168	1,757
3336	90	NO	NO		37	170,000	15	NO	20	653	1,304
3337	60	YES	NO		21	81,000	10	YES		765	1,250
3338	75	NO	NO		26	102,000	15	YES		755	1,404
3344	45	YES	YES	120	26		5	YES		720	1,100
3345	45	YES	YES	180	26		5	YES		715	1,150
3346											
3347	60	YES	YES	20	20	45,000	6	YES		565	1,400
3348	60	YES	YES	20	20	45,000	6	YES		565	1,500
3349	60	YES	YES	20	30	45,000	6	YES		565	1,350
3350	75	YES	YES	25	25	64,000	12	YES		515	1,250
3351	75	YES	YES	25	25	64,000	12	YES		515	1,100
3352	90	YES	YES	35	30	94,000	15	YES		495	1,200
3356	60	OCCAS.	YES	45	24	65,000	22	YES		750	1,620
3357	55	YES	NO		20	65,000	10	YES		682	1,341
3358	55	YES	NO		18	65,000	10	YES		745	1,427
3359	70	NO	NO		25	115,000	15	YES		687	1,208
3360	70	YES	NO		24	105,000	15	YES		636	1,233

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3361	55	YES	NO		18	65,000	10	YES		727	1,345
3409	40	YES	YES	20	20	65,000	5	YES		723	1,369
3410	40	YES	YES	20	20	65,000	5	YES		678	1,480
3411	40	YES	YES	20	25	75,000	5	YES		622	1,278
3412	40	YES	NO		28	80,000	5	YES		601	1,142
3413	45	YES	NO		28	110,000	12	NO		706	1,318
3414	40	YES	NO		24	65,000	4	YES		725	1,108
3415	50	YES	NO		30	110,000	18	YES		669	1,072
3416	60	YES	NO		38	160,000	38	YES		690	1,071
3501	30	OCCAS.	NO		20	56,000	3	YES		415	1,091
3502	40	OCCAS.	NO		25	82,000	3	YES		428	1,025
3503	60	OCCAS.	NO		25	112,000	7	YES		437	1,082
3504	100	OCCAS.	NO		36	161,000	13	YES		423	945

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BLAST FURNACE CODE	FUEL USED AT TUYERES	AMT OF FUEL AT TUYERES	UNITS	COKE QUALITY ASTM STABIL.	SILICON CONTENT HOT METAL (%)	SULFUR CONTENT HOT METAL (%)	MANGAN. CONTENT HOT METAL (%)	SLAG BASICITY (B/A)	SULFUR CONTENT OF SLAG (%)	ORE IN METAL BURDEN (%)	SINTER IN METAL BURDEN (%)
0993	OIL	6	GPM							60.0	35.0
0999	OIL	6	GPM							60.0	35.0
1001				51	0.70	0.030	0.70	1.18	1.200	74.0	26.0
1002	TAR	9	GPM	53	1.05	0.028	0.75	1.03	1.670	7.0	
1003											
1101				50	1.00	0.030	0.65	1.07	1.100	5.0	14.0
1102				50	1.00	0.030	0.65	1.07	1.100	3.0	17.0
1201	NATURAL GAS	158,854	CFH	48	1.00	0.025	0.47	0.95	1.620	15.0	28.0
1301				56	1.04	0.031	0.74	0.96	1.600	10.0	32.0
1302	TAR	6	GPM	55	1.28	0.031	0.76	0.97	1.700	20.0	44.0
1303	TAR	17	GPM	56	1.35	0.029	0.82	1.01	1.700	9.0	39.0
1304				55	1.60	0.033	0.75	0.92	1.600	15.0	39.0
1401				45	1.50	0.028	0.39	0.98	1.330	72.0	25.0
1402				46	1.47	0.038	0.33	0.97	1.320	62.0	35.0
1403				58	1.10	0.030	0.54	0.97	0.900	20.0	37.0
1404				57	1.20	0.030	0.50	0.95	1.900	20.0	37.0
1405				46	1.50	0.027	0.41	0.96	1.320	62.0	35.0
1406				48	1.36	0.034	0.39	1.00	1.220	62.0	35.0
1407				46	1.40	0.032	0.60	0.99	1.240	40.0	40.0
1408				58	1.05	0.030	0.45	0.97	1.000	15.0	38.0
1409	TAR OR OIL	25	GPM	58	1.10	0.030	0.47	0.98	1.100	14.0	33.0
1410	TAR OR OIL	25	GPM	46	1.33	0.027	0.86	0.96	1.040	30.0	40.0
1503	TAR	17	GPM	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1504	TAR	17	GPM	57	1.50	0.025	0.90	1.25	1.500	10.0	25.0
1505	TAR	17	GPM	57	1.50	0.025	0.90	1.25	1.500	10.0	25.0
1506	TAR	17	GPM	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1507	TAR	17	GPM	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1602				60	1.15	0.021	1.20	1.11	1.550	10.0	38.0
1603				60	1.22	0.027	0.68	1.12	1.560	15.0	31.0
1604				60	1.16	0.027	0.60	1.11	1.580	12.0	34.0
1701	TAR	45	GPM	60	1.01	0.031	0.82	1.17	1.710		33.0
1702	OIL	54	GPM	60	0.97	0.031	0.80	1.20	1.650		33.0
1804	TAR	5	GPM	44	1.42	0.053	0.45	0.88	1.150	45.0	50.0
1805	TAR	5	GPM	44	1.40	0.053	0.45	0.88	1.150	45.0	50.0
1806	TAR	5	GPM	44	1.42	0.053	0.45	0.88	1.150	45.0	51.0
1807	TAR	5	GPM	44	1.40	0.053	0.45	0.88	1.150	46.0	48.0
2002				50	1.60	0.020	0.40	1.00	1.500	31.0	4.0
2101	NATURAL GAS	132,104	CFH	51	1.09	0.026	0.75	1.05	1.160	5.0	
2102	NATURAL GAS	119,167	CFH	51	1.01	0.028	0.78	1.06	1.250	5.0	
2103	NATURAL GAS	156,583	CFH	51	1.08	0.026	0.74	1.06	1.070	5.0	
2201	OIL	30	GPM	51	1.40	0.017	0.79	1.23	1.940	16.0	23.0
2202	OIL	30	GPM	51	1.24	0.026	0.72	1.23	1.840	0.0	23.0
2203	OIL	30	GPM	51	1.19	0.026	0.91	1.26	1.960	0.0	19.0
2204	OIL	28	GPM	51	1.12	0.034	0.78	1.25	1.960	0.0	18.0
2205	OIL	48	GPM	51	1.15	0.020	0.74	1.28	2.000	0.0	19.0
2206	OIL	48	GPM	51	1.69	0.025	0.60	1.24	2.130	0.0	19.0

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2207	TAR	35	GPM	51	0.91	1.759	0.78	1.19	1.570	0.0	0.0
2208	OIL	44	GPM	51	0.92	0.034	0.78	1.21	1.750	0.0	0.0
2301	COKE OVEN GAS	90	CFH	49	1.03	0.030	0.90	1.15	1.700		45.0
2302	OIL	15	GPM	49	1.75	0.030	0.90	1.13	1.800		30.0
2303											
2304	TAR	15	GPM	45	3.50	0.027	0.85	0.91	1.950	1.0	
2501	NATURAL GAS	105,000	CFH	49	1.20	0.035	[illegible]	1.08	1.940	30.0	0.0
2502	OIL	32	GPM	48	1.38	0.026	0.73	1.08	1.950	8.0	62.0
2503	OIL	30	GPM	48	1.37	0.031	0.72	1.03	2.050	0.0	50.0
2504				48	1.32	0.029	0.68	1.05	1.880	12.0	50.0
2505	OIL	22	GPM	48	1.32	0.032	0.76	1.03	1.910	11.0	49.0
2506	OIL	18	GPM	48	1.40	0.029	0.68	1.04	1.960	10.0	48.0
2512	OIL	26	GPM	50	1.20	0.041	0.70	1.10	1.690	1.0	
2514	OIL	26	GPM	50	1.20	0.036	0.73	1.09	1.830	5.0	32.0
2601	NATURAL GAS OR OIL	110,000	CFH	36	1.20	0.030	0.27	1.12	1.350	27.0	23.0
2602	NATURAL GAS	110,000	CFH	36	1.20	0.030	0.25	1.12	1.300	27.0	23.0
2603	NATURAL GAS OR OIL	110,000	CFH	36	1.20	0.030	0.25	1.12	1.350	27.0	23.0
2604	NATURAL GAS OR OIL	125,000	CFH	48	1.20	0.035	0.25	1.12	1.350	27.0	23.0
2701	NATURAL GAS			57	0.92	0.032	0.36	0.88	1.100	83.0	26.0
2801	NATURAL GAS	180,000	CFH	50	0.90	0.019	1.10	1.10	1.100		
2802	NATURAL GAS	180,000	CFH	50	1.00	0.017	1.10	1.10	1.100		
2901	OIL	35	GPM	50	1.00	0.059	0.90	1.00	1.750		33.0
2902	OIL	35	GPM	50	1.00	0.050	0.90	1.00	1.750		33.0
2907	OIL	30	GPM	50	1.00	0.025	0.75	1.28	2.250	5.0	33.0
2908	OIL	33	GPM	50	1.00	0.025	0.75	1.25	2.250	5.0	33.0
2909	OIL	50	GPM	50	1.00	0.025	0.75	1.25	2.250	5.0	33.0
2910	TAR	60	GPM	50	1.00	0.025	0.75	1.25	2.250	5.0	33.0
2911				51	2.25	0.025	1.00	1.10	1.800	80.0	
2912				51	2.25	0.025	1.00	1.10	1.750	88.0	
2913				51	2.25	0.025	1.00	1.10	1.750	89.0	
3001	TAR	28	GPM	45	1.19	0.042	0.57	1.07	1.490	15.0	
3002	TAR	25	GPM	50	1.42	0.037	0.88	1.02	1.570	33.0	2.0
3003	OIL	36	GPM	52	1.45	0.034	0.89	1.08	1.800	46.0	1.0
3008				42	1.17	0.035	0.27	1.06	1.510	12.0	
3009	OIL	75	GPM	42	1.23	0.040	0.28	1.07	1.580	12.6	
3010	TAR OR OIL	92	GPM	45	1.33	0.024	0.40	1.08	1.590	11.0	
3011	TAR OR OIL	5	GPM	45	1.24	0.028	0.33	1.07	1.530	11.0	
3014											
3015	OIL	91	GPM	51	1.28	0.030	0.53	1.19	1.520	15.0	
3016	TAR OR OIL	25	GPM	44	1.14	0.034	0.88	1.02	1.360		
3017	NATURAL GAS	47,958	CFH	54	1.10	0.051	0.48	0.90	1.700	37.0	24.0
3018	NATURAL GAS	45,625	CFH	54	1.31	0.046	0.47	0.95	1.900	32.0	22.0
3201				52	1.60	0.028	1.00	1.05	2.000	40.0	
3301	OIL	40	GPM	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0
3302	OIL	40	GPM	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0
3303	OIL	40	GPM	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0

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3304	TAR	10	GPM	50	1.20	0.025	0.70	1.10	1.750	10.0	60.0
3305	TAR	10	GPM	50	1.10	0.028	0.80	1.10	1.750	19.0	47.0
3306	TAR	10	GPM	50	1.50	0.040	0.70	1.00	1.800	19.0	47.0
3308	TAR	10	GPM	50	1.20	0.025	0.85	1.10	1.700		47.0
3309				50	1.20	0.030	0.80	1.05	1.750	40.0	60.0
3310				52	1.00	0.033	0.90	1.05	1.800	10.0	48.0
3311	TAR	18	GPM	52	1.05	0.035	0.90	1.05	1.800	10.0	50.0
3312	OIL	16	GPM	52	1.20	0.030	0.70	1.00	1.950	57.0	38.0
3313	OIL	16	GPM	52	1.30	0.030	0.50	1.05	1.900	24.0	47.0
3315	OIL	10	GPM	50	1.00	0.030	0.80	1.08	1.450	40.0	40.0
3316	OIL	7	GPM	50	1.00	0.030	0.80	1.08	1.750	10.0	60.0
3317	OIL	15	GPM	50	1.00	0.030	0.80	1.08	1.750	10.0	60.0
3318	OIL	50	GPM	50	1.00	0.030	0.80	1.10	1.700		52.0
3320	OIL	10	GPM	46	0.93	0.033	0.86	1.15	1.840	17.0	60.0
3321				46	1.22	0.036	0.99	1.15	1.970	7.0	66.0
3322											
3323				46	1.22	0.023	1.36	1.12	1.590	20.0	80.0
3324				52	1.61	0.031	0.58	1.76	2.100	20.0	48.0
3325	TAR OR OIL	30	GPM	52	1.32	0.030	0.40	1.71	2.180		47.0
3326					1.19	0.025	0.96	1.42	1.250		
3327	TAR OR OIL	14	GPM	52	1.50	0.026	0.53	2.00	2.450	20.0	52.0
3328											
3329	TAR OR OIL	24	GPM	52	1.40	0.027	0.37	1.28	1.620		49.0
3330					1.34	0.063	0.83	1.14	1.560		
3331	TAR OR OIL	30	GPM	52	1.50	0.032	0.33	1.30	1.720		48.0
3332				52	1.40	0.030	0.43	1.43	1.890	44.0	46.0
3333				52	1.21	0.024	0.72	1.43	1.890	38.0	60.0
3334				53	1.40	0.031	0.42	1.06	1.650		30.0
3335					1.00	0.027	0.65	1.14	1.800	39.0	63.0
3336	OIL	32	GPM	53	1.20	0.033	0.69	1.14	1.730		22.0
3337	OIL	12	GPM	53	1.39	0.034	0.89	1.13	1.650	19.0	27.0
3338	OIL	10	GPM	53	1.31	0.059	0.81	1.13	1.690	5.0	29.0
3344				50	1.00	0.028	0.14	1.14	0.085		11.0
3345				50	1.00	0.032	0.16	1.11	0.860		28.0
3346											
3347				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3348				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3349				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3350	TAR			50	1.20	0.025	0.37	1.00	1.400	20.0	80.0
3351	TAR			50	1.20	0.025	0.37	1.00	1.400	20.0	80.0
3352				50	1.20	0.025	0.40	1.00	1.500	30.0	40.0
3356				45	2.00	0.018	1.00	1.15	1.900	93.0	
3357	TAR OR OIL	15	GPM	50	1.26	0.026	0.89	1.04	1.250	52.0	
3358	TAR OR OIL	15	GPM	50	1.29	0.029	1.03	1.06	1.320	52.0	
3359	TAR	10	GPM	50	1.24	0.030	0.77	1.06	1.160	29.0	
3360	TAR	10	GPM	50	1.16	0.029	0.82	1.06	1.170	29.0	

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3361	TAR OR OIL	9	GPM	50	1.22	0.027	0.90	1.06	1.230	52.0	
3409	TAR	12	GPM	50	0.98	0.028	1.02	1.21	2.050	15.0	22.0
3410				48	1.27	0.041	0.85	1.21	2.170	1.0	30.0
3411				49	1.43	0.049	0.85	1.11	2.120		22.0
3412	TAR	23	GPM	49	1.35	0.034	0.60	1.14	2.090		
3413				41	1.22	0.033	1.03	1.19	1.410		
3414	OIL	21	GPM	44	1.06	0.029	1.69	1.15	1.170		
3415	OIL	34	GPM	46	1.10	0.029	1.26	1.23	1.650		
3416	OIL	23	GPM	46	0.97	0.031	1.22	1.11	1.360		
3501	NATURAL GAS	90,854	CFH	53	1.17	0.032	1.52	1.05	1.380	3.0	3.0
3502	GAS OR TAR	20	GPM	53	1.15	0.032	1.56	1.07	1.440		4.0
3503		17	GPM	53	1.24	0.035	1.43	1.07	1.420	2.0	6.0
3504	NATURAL GAS	366,917	CFH	54	1.09	0.031	1.32	1.06	1.320	2.0	6.0

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0998	5.0					NO						NO	181,760
0999	5.0					NO						NO	181,760
1001		100.0	YES	NO	NO	NO	2650	3.0	14	20	4	YES	342,500
1002	7.0	87.0	YES	NO	NO	NO	2740	1.0	1	35	7	NO	455,740
1003			YES	NO	NO	NO	2740	1.0	1			NO	312,117
1101		81.0	YES	NO	NO	NO	2780	1.0	3	3	3	NO	641,000
1102		80.0	YES	NO	NO	NO	2780	1.0			2	NO	305,000
1201	3.0	55.0	YES	NO	NO	NO	2725	7.0	6		6	YES	580,580
1301	2.0	58.0	NO	NO	NO	NO	2720	1.0	8	16	16	NO	769,336
1302		36.0	NO	NO	NO	NO	2720	1.0	8	16	16	NO	546,609
1303	2.0	52.0	NO	NO	NO	NO	2750	1.0	8	16	16	NO	682,714
1304		46.0	NO	NO	NO	NO	2750	1.0	8	16	16	NO	463,468
1401			YES	NO	NO	NO	2650	1.0	3	15	3	NO	526,235
1402			YES	NO	NO	NO	2650	1.0	3	15	3	NO	461,427
1403		40.0	YES	NO	NO	NO	2810	1.0	3	20	3	NO	455,378
1404		40.0	YES	NO	NO	NO	2810	1.0	3	20	3	NO	454,012
1405			YES	NO	NO	NO		1.0	3	10	3	NO	423,199
1406			YES	NO	NO	NO		1.0	3	10	3	NO	423,199
1407		15.0	YES	NO	NO	NO	2850	1.0	3	20	3	NO	477,761
1408		45.0	YES	NO	NO	NO	2810	1.0	3	20	3	NO	596,667
1409		50.0	YES	NO	NO	NO	2810	1.0	4	30	5	NO	1,088,118
1410		27.0	YES	NO	NO	NO	2820	1.0	3	20	3	NO	753,417
1503	5.0	65.0	YES	NO	NO	NO	2700	2.0	16	56	8	NO	374,258
1504	5.0	60.0	YES	NO	NO	NO	2700	2.0	16	56	8	NO	233,132
1505	5.0	60.0	YES	NO	NO	NO	2700	2.0	16	56	8	NO	426,524
1506	5.0	65.0	YES	NO	NO	NO	2700	2.0	16	56	8	NO	379,585
1507	5.0	65.0	YES	NO	NO	NO	2700	2.0	16	56	8	NO	465,362
1602	4.0	49.0	NO	NO	NO	NO	2800	3.0	24	24		NO	311,888
1603	7.0	47.0	NO	NO	NO	NO	2800	3.0	8	24		NO	672,255
1604	8.0	46.0	NO	NO	NO	NO	2800	3.0	8	24		NO	665,574
1701	2.0	65.0	YES	YES	YES	NO	2789	2.0	10	15	7	NO	685,403
1702	2.0	65.0	YES	YES	YES	NO	2788	2.0	10	15	7	NO	699,506
1804	5.0		YES	NO	NO	NO	2575	1.0	1	30	15	NO	174,680
1805	5.0		YES	NO	NO	NO	2575	1.0	1	30	15	NO	181,074
1806	4.0		YES	NO	NO	NO	2575	1.0		30	15	NO	180,700
1807	6.0		YES	NO	NO	NO	2575	1.0	1	30	15	NO	177,318
2002	4.0	61.0	YES	NO		NO	2650	1.0	3	35	5	NO	433,111
2101		95.0	NO	NO		NO	2700	1.0	3	28	0	NO	410,000
2102		90.0	NO	NO		NO	2700	1.0	3	28	0	NO	410,000
2103	8.0	88.0	YES	NO		NO	2700	1.0	3	28	0	NO	719,230
2201		54.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	160,000
2202		75.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	145,000
2203		72.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	220,000
2204		76.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	322,000
2205		79.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	400,000
2206		77.0	YES	NO	NO	NO	2800	8.0	35	40	40	NO	440,000

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BLAST FURNACE CODE	SCRAP IN METAL BURDEN (%)	PELLETS IN METAL BURDEN (%)	COKE SCREENED AT STOCK HOUSE?	ORE SCREENED AT STOCK HOUSE?	SINTER SCREENED AT STOCK HOUSE?	LARGE QUAN OF COKE ASSOC W/ CAST?	HOT METAL TEMP (DEG F)	FREQ IRON RUNNER REMAKE (DAYS)	NO. OF CASTS BETWEEN RUNNER RELINE	NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	TILTING SPOUTS USED?	CAST HOUSE VOLUME (CU FT)
2207	0.0	100.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	332,000
2208	0.0	100.0	YES	NO	NO	NO	2700	8.0	35	40	40	NO	393,000
2301		55.0	NO	NO	NO	NO	2770	3.0	24	48	3	NO	481,419
2302		70.0	NO	NO	NO	NO	2750	3.0	24	48	3	NO	403,982
2303												NO	
2304	1.0	99.0	NO	NO	NO	NO	2750	1.0	3	20	6	NO	593,024
2501	0.0	70.0	YES	NO	NO	NO	2725	1.0	1	16	2	NO	414,000
2502		30.0	YES	NO	NO	NO	2720	1.0		250		NO	512,000
2503	5.0	45.0	YES	YES	YES	NO	2720	1.0		250	2	NO	512,000
2504	5.0	33.0	YES	NO	NO	YES	2700	1.0	1	520	6	NO	404,000
2505	0.0	40.0	YES	NO	NO	NO	2730	1.0		250	3	NO	404,000
2506	5.0	37.0	YES	NO	NO	NO	2710	1.0		400	6	NO	277,000
2512		94.0	YES	NO	NO	NO	2730	1.0	4		1	NO	767,143
2514		63.0	YES	YES	YES	NO	2720	1.0	4		1	NO	801,735
2601	5.0	20.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	322,094
2602	5.0	50.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	322,094
2603	5.0	50.0	YES	NO	NO	OCCAS.						NO	305,557
2604	5.0	50.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	404,773
2701	17.0	24.0	YES	NO	NO	NO	2750	2.0	16		32	NO	502,000
2801	2.0	98.0	YES			NO	2690	2.0	16	24	24	NO	571,893
2802	2.0	98.0	YES			NO	2700	2.0	16	24	24	NO	571,893
2901	2.0	65.0	YES	NO	NO	NO	2550	1.0	2	7	7	NO	165,700
2902	2.0	65.0	YES	NO	NO	NO	2550	1.0	2	7	7	NO	165,700
2907	7.0	55.0	YES	NO	NO	OCCAS.	2650	5.0	38	0	8	NO	793,912
2908	7.0	55.0	YES	NO	NO	OCCAS.	2650	5.0	38	0	8	NO	342,864
2909	7.0	55.0	YES	NO	NO	OCCAS.	2650	5.0	38	0	8	NO	410,924
2910	7.0	55.0	YES	NO	NO	OCCAS.	2650	5.0	38	0	8	NO	600,413
2911	12.0	8.0	NO	NO		NO	2600	1.0	1	35	1	NO	215,826
2912	12.0		NO	NO		NO	2600	1.0	1	35	1	NO	230,809
2913	11.0		NO	NO		NO	2600	1.0	1	42	1	NO	322,551
3001	3.0	83.0	YES	NO		NO	2600	7.0	21	42	21	NO	621,217
3002	4.0	61.0	YES	NO	NO	NO	2650	1.0	3	6	6	NO	437,033
3003	11.0	42.0	YES	NO	NO	NO	2650	1.0	3	6	6	NO	364,763
3008		88.0	YES	NO	NO	NO	2700	2.0	12	30	0	NO	354,038
3009		87.0	YES	NO	NO	NO	2700	2.0	12	30	0	NO	453,603
3010	10.0	78.0	YES	NO		NO	2700	2.0	12	30	0	NO	465,227
3011	8.0	81.0	YES	NO		NO	2700	2.0	12	30	0	NO	485,207
3014			NO	NO	NO	NO		1.0	2	18	1	NO	221,769
3015	7.0	79.0	NO	NO	NO	NO		1.0	2	18	1	NO	375,033
3016	5.0	83.0	YES	NO		NO	2650	1.0	3		1	NO	550,670
3017		39.0	NO	NO	NO	NO	2450	1.0	7	35		NO	159,063
3018	3.0	43.0	YES	NO	NO	NO	2500	1.0	6	30	6		360,629
3201	11.0	49.0	YES	NO	NO	NO	2730	10.0	60	42	0	NO	329,029
3301	7.0	16.0	YES	NO	NO	NO	2700	1.0	3	2	2	NO	397,478
3302	7.0	16.0	YES	NO	NO	NO	2700	1.0	3	2	2	NO	394,228
3303	7.0	16.0	YES	NO	NO	NO	2700	1.0	3	2	2	NO	394,228

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3304		30.0	YES	NO	NO	NO	2710	1.0	4	16	4	NO	440,330
3305	6.0	28.0	YES	NO	NO	NO	2710	1.0	4	18	3	NO	440,330
3306	7.0	28.0	YES	NO	NO	NO	2720	1.0	4	16	3	NO	856,023
3308	7.0	47.0	YES	NO	NO	NO	2710	1.0	4	20	5	NO	212,436
3309			YES	NO	NO	NO	2680	1.0	4	20	4	NO	213,643
3310	3.0	39.0	YES	NO	NO	NO	2680	2.0	14	35	14	NO	342,265
3311	6.0	34.0	YES	NO	NO	NO	2680	2.0	14	35	14	NO	342,265
3312	5.0		YES	NO	NO	NO	2660	2.0	12	30	12	NO	451,349
3313	5.0	24.0	YES	NO	NO	NO	2660	2.0	12	30	12	NO	453,349
3315		20.0	YES	NO	NO	NO	2680	1.0	8	8	8	NO	349,078
3316	1.0	29.0	YES	NO	NO	NO	2680	1.0	8	8	8	NO	371,340
3317	2.0	23.0	YES	NO	NO	NO	2680	1.0	9	9	9	NO	237,741
3318		50.0	YES	NO	NO	NO	2680	1.0	11	11	11	NO	953,385
3320	6.0	17.0	YES	NO	NO	NO	2690	5.0	40	6	3	NO	174,854
3321	10.0	17.0	YES	NO	NO	NO	2690	5.0	40	6	3	NO	176,485
3322			YES	NO	NO	NO	2690	5.0	40	6	3	NO	184,423
3323			YES	NO	NO	NO	2690	5.0	40	6	3	NO	201,050
3324	4.0	28.0	NO	NO	NO	NO	2695	1.0	3	30	5	NO	173,765
3325	2.0	52.0	YES	NO	NO	NO	2720	1.0	3	30	5	NO	147,715
3326			NO	NO	NO	NO	2700	1.0	3	30	5	NO	172,558
3327	2.0	28.0	YES	NO	NO	NO	2675	1.0	3	30	5	NO	137,512
3328			YES	NO	NO			1.0	3	30	5	NO	144,092
3329		51.0	YES	NO	NO	NO	2685	1.0	3	30	5	NO	208,781
3330			NO	NO	NO	NO	2650	1.0	3	30	5	NO	152,290
3331		52.0	YES	NO	NO	NO	2690	1.0	3	30	5	NO	131,618
3332	10.0		NO	NO	NO	NO	2650	1.0	3	30	5	NO	146,149
3333	2.0		NO	NO	NO	NO	2690	1.0	3	30	5	NO	146,149
3334		70.0	YES	NO	NO	NO	2772	5.0	30	90	30	YES	1,491,259
3335	3.0		YES	NO	NO	NO	2730	1.0	1	60	30	NO	549,637
3336		78.0	YES	NO	NO	NO	2700	2.0	20	20	20	NO	268,000
3337	1.0	54.0	YES	NO	NO	NO	2720	1.0	6	20	6	NO	277,480
3338	1.0	65.0	YES	NO	NO	NO	2700	1.0	6	20	6	NO	277,480
3344	1.0	89.0	YES	NO	NO	NO	2650	1.0	2	40	25	NO	469,932
3345	1.0	72.0	NO	NO	NO	NO	2650	1.0	2	40	25	NO	556,896
3346												NO	556,896
3347	2.0		NO	NO	NO	OCCAS.	2675	1.0	5	19	3	NO	478,870
3348	2.0		NO	NO	NO	OCCAS.	2675	1.0	5	19	3	NO	478,670
3349	2.0		NO	NO	NO	OCCAS.	2675	1.0	5	19	3	NO	484,000
3350			NO	NO	NO	OCCAS.	2700	1.0	5	6	3	NO	419,547
3351			NO	NO	NO	OCCAS.	2700	1.0	5	6	3	NO	346,000
3352		30.0		NO	NO	OCCAS.	2700	1.0	5	6	3	NO	530,020
3356	7.0		YES	NO	NO	NO	2725	1.0	1	30	18	NO	570,936
3357	3.0	45.0	NO	NO	NO	NO	2730	1.0	9	56	8	NO	230,804
3358	3.0	45.0	NO	NO	NO	NO	2700	1.0	9	56	8	NO	230,442
3359	3.0	68.0	NO	NO	NO	NO	2710	1.0	9	56	8	NO	375,444
3360	3.0	68.0	NO	NO	NO	NO	2720	1.0	9	56	8	NO	374,619

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3361	3.0	45.0	NO	NO	NO	NO	2700	1.0	9	56	8	NO	230,079
3409		49.0	NO	NO	NO	NO		1.0	1	60	6	NO	360,000
3410	7.0	63.0	NO	NO	NO	NO		1.0	1	60	6	NO	360,000
3411	1.0	66.0	NO	NO	NO	NO		1.0	1	60	6	NO	350,000
3412	1.0	94.0	NO	NO	NO	NO		1.0	1	75	8	NO	490,000
3413		91.0	YES	NO	NO	NO	2700	1.0	7	14	10	NO	335,000
3414		84.0	YES	NO	NO	NO	2700	1.0	7	14	10	NO	250,000
3415		83.0	YES	NO	NO	NO	2700	1.0	7	14	10	NO	450,000
3416		87.0	YES	NO	NO	NO	2700	1.0	9	8	6	NO	790.000
3501	7.0	87.0	YES	NO	NO	NO	2675	5.0	40	40	24	NO	406,013
3502	6.0	87.0	YES	NO	NO	NO	2675	4.0	40	32	16	NO	283,399
3503	7.0	86.0	YES	NO	NO	NO	2675	4.0	40	32	16	NO	1,227,409
3504	7.0	86.0	YES	YES	NO	NO	2700	5.0	25	25	15	NO	954,598

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0998	644		.907185E+06	6	5.486		1	1			
0999	644		.907185E+06	6	5.944		1	1			
1001	1,566	.364325E+07	.338743E+07	10	7.772	101.60	2	2	8.53	914.40	762.00
1002	670	.146964E+07	.112582E+07	7	5.639	98.90	1	1	6.71	1219.20	635.00
1003	864	.163112E+07			5.944	88.90	1	2	6.40	1219.20	635.00
1101	2,038	.402427E+07	.321143E+07	10	10.211	88.90	2	1	9.45	914.40	609.60
1102	1,487	.331304E+07	.185701E+07	7	8.763	88.90	1	2	7.32	914.40	431.80
1201	1,424	.281046E+07		6	8.306	88.90	1	1	9.75	990.60	762.00
1301	1,541	.350536E+07	.257187E+07	8	9.144	88.90	1	1	5.79	1219.20	609.60
1302	1,468	.304723E+07	.187062E+07	8	8.534	88.90	1	1	5.79	1219.20	609.60
1303	1,552	.344730E+07	.239769E+07	8	9.144	88.90	1	1	5.79	1219.20	609.60
1304	1,125	.241946E+07	.160300E+07	8	7.315	88.90	1	1	5.79	1219.20	609.60
1401	1,131	.195589E+07	.149686E+07	7	7.772	88.90	1	2	9.14	914.40	508.00
1402	1,101	.199671E+07	.149686E+07	7	7.772	88.90	1	2	7.32	914.40	508.00
1403	1,196	.250383E+07	.216091E+07	8	8.534	88.90	1	2	9.14	914.40	508.00
1404	1,213	.229064E+07	.191597E+07	7	8.534	88.90	1	2	7.32	914.40	508.00
1405	704	.126552E+07	.816467E+06	5	6.020	88.90	1	1	6.10	914.40	508.00
1406	707	.124557E+07	.816467E+06	5	6.020	88.90	1	1	6.10	914.40	508.00
1407	1,335	.225889E+07		7	8.534	88.90	1	2	6.71	914.40	508.00
1408	1,543	.318785E+07	.242581E+07	8	9.144	88.90	1	2	8.53	914.40	508.00
1409	1,552	.432909E+07	.272246E+07	8	9.144	88.90	2	2	9.14	914.40	508.00
1410	1,551	.344912E+07	.254012E+07	8	9.144	88.90	1	2	9.14	914.40	508.00
1503	1,445	.310257E+07	.200941E+07	8	8.992	88.90	1	1	7.62	1524.00	1219.20
1504	1,117	.241856E+07	.150230E+07	8	7.925	88.90	1	1	8.84	1524.00	1219.20
1505	1,132	.241856E+07	.182163E+07	8	8.230	88.90	1	2	6.10	609.60	1219.20
1506	1,440	.274151E+07	.205840E+07	8	8.839	101.60	1	1	7.62	1524.00	1219.20
1507	1,560	.338017E+07	.235142E+07	8	9.144	101.60	1	2	7.62	1524.00	1219.20
1602	943	.155854E+07	.146510E+07	8	7.925	76.20	1	2	5.18	762.00	609.60
1603	1,347	.254012E+07	.222895E+07	8	7.925	76.20	1	2	7.62	762.00	508.00
1604	1,375	.247389E+07	.227068E+07	8	8.534	76.20	1	2	7.62	762.00	508.00
1701	2,525	.527891E+07	.464025E+07	9	11.659	57.15	2	1	8.23	609.60	609.60
1702	2,453	.520633E+07	.520633E+07	10	10.668	57.15	2	1	8.23	609.60	609.60
1804	938	.109769E+07	.725748E+06	6	6.934	76.20	1	1	8.84	863.60	533.40
1805	868	.958395E+06	.725748E+06	6	6.401	76.20	1	1	8.84	863.60	533.40
1806	698	.998811E+06	.725748E+06	6	6.492	76.20	1	1	8.84	863.60	533.40
1807	886	.120111E+07	.725748E+06	6	6.629	76.20	1	1	6.71	685.80	431.80
2002	1,541	.231332E+07	.132177E+07	5	8.915	82.55	1	2	6.40	1676.40	609.60
2101	794	.188876E+07	.155129E+07	8	6.096	88.90	1	1	7.92	711.20	381.00
2102	778	.196315E+07	.159665E+07	8	6.096	88.90	1	1	7.92	711.20	381.00
2103	1,557	.346635E+07	.282135E+07	8	8.839	88.90	1	2	7.62	762.00	381.00
2201	875	.194682E+07	.150593E+07	8	6.340	76.20	1	2	6.40	1143.00	558.80
2202	727	.190962E+07	.158213E+07	8	6.096	76.20	1	2	6.40	1066.80	685.80
2203	934	.211102E+07	.166015E+07	8	6.706	76.20	1	2	6.40	1219.20	711.20
2204	809	.214912E+07	.158667E+07	8	6.401	76.20	1	2	4.88	1524.00	685.80
2205	1,311	.296922E+07	.231241E+07	8	8.230	76.20	1	2	6.40	1320.80	660.40
2206	1,334	.293837E+07	.203209E+07	8	8.077	76.20	1	2	6.40	1320.80	660.40

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2207	1,329	.316426E+07	.232239E+07	8	8.077	76.20	1	2	8.84	1346.20	660.40
2208	1,319	.316426E+07	.232058E+07	8	8.077	76.20	1	2	8.84	1346.20	660.40
2301	1,173	.223984E+07	.174633E+07	8	7.696	88.90	1	0	8.53	1219.20	482.60
2302	765	.147145E+07	.952544E+06	8	5.992	88.90	1	0	7.32	990.60	482.60
2303	724				5.791		1	1	6.10	660.40	457.20
2304	798	.139525E+07	.861826E+06	8	6.401	88.90	1	1	7.62	1016.00	381.00
2501	1,540	.209015E+07	.207836E+07	8	8.839	81.28	1	1	9.14	1828.80	1219.20
2502	1,242	.254556E+07	.000000E+01	8	8.687	88.90	1	2	8.53	1219.20	609.60
2503	1,529	.365142E+07	.294835E+07	8	8.839	83.82	1	1	9.45	1828.80	609.60
2504	965	.197857E+07	.145150E+07	8	8.687	88.90	1	1	6.71	1219.20	457.20
2505	1,540	.278415E+07	.000000E+01	0	8.839		1	1	7.92	152.40	50.80
2506	891	.194159E+07	.136078E+07	8	8.321	88.90	1	1	7.32	1219.20	457.20
2512	1,336	.276691E+07	.209560E+07	8	8.382	76.20	1	1	5.49	1270.00	482.60
2514	1,624	.352986E+07	.249657E+07	9	9.296	76.20	2	0	7.32	1219.20	304.80
2601	1,125	.201214E+07	.167194E+07	6	8.230	63.50	1	1	7.32	762.00	660.40
2602	1,125	.215184E+07	.168464E+07	6	8.230	63.50	1	1	7.32	762.00	660.40
2603	1,125	.193412E+07	.165561E+07	6	8.230	63.50	1	1	9.75	1219.20	660.40
2604	1,450	.270613E+07	.209015E+07	6	8.992	63.50	1	1	7.32	762.00	660.40
2701	1,495	.240223E+07	.163293E+07	9	8.321	88.90	1	2	5.49	1219.20	355.60
2801	1,620	.312838E+07	.244940E+07	8	8.687	101.60	1	2	7.62	1219.20	762.00
2802	1,620	.323049E+07	.240404E+07	8	8.687	101.60	1	2	7.62	1219.20	762.00
2901	1,434	.219448E+07	.208653E+07	8	8.321	88.90	1	2	5.79	1219.20	914.40
2902	1,429	.222532E+07	.226796E+07	8	8.321	88.90	1	2	6.40	1219.20	762.00
2907	1,591	.252107E+07	.199581E+07	8	8.230	88.90	1	1	5.49	609.60	762.00
2908	1,301	.253014E+07	.190509E+07	8	8.230	88.90	1	1	7.62	609.60	762.00
2909	1,321	.251925E+07	.190509E+07	8	8.001	88.90	1	1	5.79	609.60	762.00
2910	1,321	.262449E+07	.190509E+07	8	8.001	88.90	1	1	5.49	609.60	762.00
2911	462		.635030E+06	5	4.953	69.85	1	1	3.66	1143.00	457.20
2912	476		.703068E+06	5	4.609	69.85	1	1	3.05	914.40	457.20
2913	828		.907185E+06	6	6.096	69.85	1	1	2.44	1371.60	457.20
3001	1,585	.274242E+07	.235968E+07	6	8.534	82.55	1	1	7.32	508.00	812.80
3002	1,210	.200760E+07	.185791E+07	6	8.001	63.50	1	1	4.88	1524.00	1524.00
3003	1,316	.197313E+07	.181437E+07	6	8.001	63.50	1	1	6.10	1524.00	1524.00
3008	1,270	.211465E+07	.189602E+07	6	8.230	69.85	1	2	6.71	965.20	558.80
3009	1,225	.188967E+07	.166287E+07	6	8.230	76.20	1	2	6.71	1016.00	584.20
3010	1,589	.245756E+07	.158848E+07	6	8.992	69.85	1	2	7.62	1447.80	558.80
3011	1,589	.250020E+07	.191870E+07	6	8.992	69.85	1	2	7.62	1422.40	584.20
3014	785	.140614E+07		6	6.553	63.50	1	1	7.32	660.40	457.20
3015	997	.188963E+07	.158122E+07	6	6.934	63.50	1	1	7.62	1168.40	558.80
3016	1,540	.251835E+07	.235868E+07	7	8.534	76.20	1	1	7.32	1524.00	762.00
3017	558	.958895E+06	.771107E+06	7	5.182	76.20	1	1	5.79	1320.80	609.60
3018	1,291	.181437E+07	.164382E+07	6	7.925	76.20	1	2	6.40	1473.20	609.60
3201	894	.145966E+07	.108862E+07	6	6.706	88.90	1	1	6.10	914.40	762.00
3301	1,656	.389545E+07	.258548E+07	9	8.992	82.55	1	1	9.14	914.40	762.00
3302	1,671	.342099E+07	.258548E+07	9	9.449	82.55	1	1	9.14	914.40	762.00
3303	1,671	.377117E+07	.258548E+07	9	9.449	82.55	1	1	9.14	914.40	762.00

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3304	1,307	.274877E+07	.127006E+07	8	8.839	76.20	1	2	4.88	914.40	812.80
3305	1,307	.293928E+07	.217724E+07	9	8.839	63.50	1	1	4.88	914.40	812.80
3306	1,099	.210558E+07	.175722E+07	8	7.925	63.50	1	1	4.88	1219.20	812.80
3308	985	.161297E+07	.127006E+07	8	7.620	76.20	1	1	4.88	914.40	812.80
3309	920	.140160E+07	.997904E+06	8	7.163	76.20	1	1	5.49	914.40	312.80
3310	1,452	.272065E+07	.213188E+07	7	8.992	76.20	1	2	7.01	1676.40	965.20
3311	1,452	.255282E+07	.204117E+07	7	8.992	76.20	1	2	5.18	1219.20	914.40
3312	893	.179804E+07	.825538E+06	6	7.163	76.20	1	2	5.79	1143.00	635.00
3313	893	.141521E+07	.940751E+06	6	7.163	76.20	1	2	7.32	1270.00	863.60
3315	731	.146148E+07		6	6.096	76.20	1	1	3.66	914.40	457.20
3316	921	.180711E+07	.108862E+07	8	7.010	76.20	1	1	3.66	914.40	457.20
3317	997	.231060E+07	.145150E+07	9	7.468	76.20	1	1	3.66	914.40	457.20
3318	1,643	.358610E+07	.254012E+07	11	8.534	76.20	2	2	5.49	1219.20	609.60
3320	1,068	.189330E+07	.154856E+07	7	7.620	76.20	1	1	5.49	1219.20	762.00
3321	983	.191144E+07	.158667E+07	7	7.163	76.20	1	1	5.18	1219.20	762.00
3322	954	.166196E+07		7	7.010	76.20	1	1	5.18	965.20	762.00
3323	1,057	.174361E+07	.103691E+07	7	7.620	76.20	1	1	5.18	1219.20	762.00
3324	785		.907185E+06	7	6.248	82.55	1	1	6.71	838.20	533.40
3325	1,346	.285854E+07	.237682E+07	8	8.611	82.55	1	2	7.01	1066.80	584.20
3326	773				6.248	82.55	1	1	5.79	838.20	533.40
3327	1,346	.270143E+07	.172365E+07	8	8.534	82.55	1	2	8.84	1066.80	533.40
3328	1,192		.122470E+07		8.534	82.55	1	1	9.45	1066.80	584.20
3329	1,161		.180530E+07	8	8.077	82.55	1	2	7.01	1066.80	685.80
3330	816		.907185E+06	6	7.010	82.55	1	1	6.71	838.20	533.40
3331	1,208		.195952E+07	8	8.230	82.55	1	1	6.71	1066.80	660.40
3332	1,111		.113398E+07	7	7.620	82.55	1	1	6.71	838.20	533.40
3333	1,111		.127006E+07	7	7.620	82.55	1	1	6.71	838.20	533.40
3334	2,031	.690731E+07	.562455E+07	12	12.192	47.75	3	0	14.33	609.60	406.40
3335	884	.144787E+07	.997904E+06	7	7.315	57.15	1	1	5.79	1371.60	1219.20
3336	1,940	.341646E+07	.298101E+07	10	9.754	76.20	2	1	12.50	1066.80	787.40
3337	1,025	.151681E+07	.151046E+07	7	7.711	76.20	1	1	9.14	762.00	635.00
3338	1,444	.233419E+07	.218541E+07	7	8.839	76.20	1	1	9.45	1016.00	711.20
3344	1,236	.204933E+07	.170006E+07	6	8.077	101.60	1	2	6.40	685.80	812.80
3345	1,236	.201759E+07	.188332E+07	6	8.077	101.60	1	2	6.40	685.80	812.80
3346	1,236	.203391E+07			8.077	101.60	1	2			
3347	882	.113942E+07	.771107E+06	5	6.706	83.82	1	1	7.92	914.40	914.40
3348	941	.117934E+07	.816467E+06	5	6.858	83.82	1	1	7.92	914.40	914.40
3349	982	.104689E+07	.839146E+06		6.553	83.82	1	1	7.01	914.40	914.40
3350	1,156	.142428E+07	.117934E+07	5	7.620	83.82	1	1	7.62	1219.20	1219.20
3351	1,160	.155129E+07	.127006E+07	5	7.620	83.82	1	1	7.62	1219.20	1219.20
3352	1,474	.218359E+07	.172365E+07	5	8.748	83.82	1	1	7.92	1828.80	1524.00
3356	1,193	.168192E+07	.997904E+06	6	7.925	82.55	1	2	7.32	1219.20	533.40
3357	810	.161842E+07		9	7.010	82.55	1	1	5.49	1524.00	685.80
3358	810	.164745E+07	.136078E+07	9	7.087	82.55	1	1	7.01	1524.00	736.60
3359	1,373	.319420E+07	.254012E+07	9	8.687	82.55	1	1	7.01	1574.80	762.00
3360	1,385	.288394E+07	.208653E+07	9	8.839	82.55	1	1	5.18	1524.00	609.60

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3361	833	.161479E+07		9	7.163	82.55	1	1	4.88	1524.00	685.80
3409	871	.120383E+07		6	6.858	88.90	1	1	5.49	660.40	457.20
3410	865	.131542E+07		6	6.706	88.90	1	1	5.49	660.40	457.20
3411	1,222	.143880E+07	.118660E+07	6	7.468	88.90	1	1	6.10	660.40	508.00
3412	1,164	.165833E+07	.161660E+07	8	7.254	88.90	1	1	6.10	711.20	508.00
3413	1,364	.218178E+07		7	8.382	88.90	1	2	8.53	762.00	609.60
3414	833	.146783E+07		7	6.949	88.90	1	2	8.23	609.60	609.60
3415	1,585	.284130E+07	.228429E+07	6	8.992	76.20	1	1	7.01	762.00	762.00
3416	1,812	.377843E+07	.373397E+07	9	9.997	76.20	2	1	10.67	762.00	914.40
3501	675	.171639E+07	.124919E+07	8	5.791	88.90	1	1	4.88	838.20	381.00
3502	1,069	.257913E+07	.216999E+07	8	7.620	88.90	1	1	5.49	1524.00	558.80
3503	1,497	.342372E+07	.269071E+07	8	8.839	88.90	1	1	6.71	1828.80	812.80
3504	2,109	.601373E+07	.421387E+07	10	9.754	76.20	2	1	9.14	1828.80	812.80

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0998	30	YES	NO		.124106E+06	.235973E+02	.689476E+05			226	589
0999	30	YES	NO		.124106E+06	.235973E+02	.689476E+05			226	589
1001	45	YES	NO		.206843E+06	.660726E+02	.137895E+06	YES		272	521
1002	25	OCCAS.	YES	12	.151685E+06	.231254E+02	.965266E+05	YES		313	566
1003								YES			
1101	50	NO	NO		.193053E+06	.689043E+02	.151685E+06	NO	3	299	487
1102	45	NO	YES	20	.144790E+06	.509703E+02	.103421E+06	YES		324	533
1201	55	NO	NO		.179264E+06	.448350E+02	.165474E+06	YES		273	520
1301	45	NO	NO		.186158E+05	.566336E+02	.551581E+05	YES		267	517
1302	45	NO	NO		.186158E+06	.519142E+02	.551581E+05	YES		263	539
1303	45	NO	NO		.186158E+06	.566336E+02	.551581E+05	YES		258	534
1304	45	NO	NO		.186158E+06	.471947E+02	.551581E+05	YES		278	541
1401	45	OCCAS.	NO		.137895E+06	.353960E+02	.689476E+05	YES		342	725
1402	45	OCCAS.	NO		.137895E+06	.353960E+02	.689476E+05	YES		353	716
1403	50	OCCAS.	NO		.151685E+06	.471947E+02	.689476E+05	YES		272	508
1404	40	OCCAS.	NO		.124106E+06	.462508E+02	.689476E+05	YES		272	517
1405	30	OCCAS.	YES	25	.110316E+06	.259571E+02	.275790E+05	YES		335	757
1406	30	OCCAS.	YES	25	.110316E+06	.259571E+02	.275790E+05	YES		335	680
1407	45	OCCAS.	NO		.124106E+06	.401155E+02	.689476E+05	YES		340	725
1408	55	OCCAS.	NO		.165474E+06	.514422E+02	.689476E+05	YES		254	526
1409	60	OCCAS.	NO		.186158E+06	.613531E+02	.186158E+06	YES		244	571
1410	55	OCCAS.	NO		.172369E+06	.519142E+02	.689476E+05	YES		324	578
1503	45	NO	NO		.172369E+06	.528581E+02	.172369E+06	YES		408	506
1504	35	NO	NO		.151685E+06	.495544E+02	.151685E+06	YES		408	706
1505	35	NO	NO		.151685E+06	.495544E+02	.151685E+06	YES		408	542
1506	45	NO	NO		.172369E+06	.519142E+02	.172369E+06	YES		408	601
1507	45	NO	NO		.206843E+06	.566336E+02	.206843E+06	YES		408	596
1602	45	YES	NO		.137895E+06	.325171E+02	.344738E+05	YES		264	566
1603	45	YES	NO		.151685E+06	.518198E+02	.344738E+05	YES		260	503
1604	45	YES	NO		.165474E+06	.491769E+02	.344738E+05	YES		262	521
1701	103	OCCAS.	NO		.220632E+06	.875462E+02	.220632E+06	NO	2	246	431
1702	93	OCCAS.	NO		.262001E+06	.900947E+02	.262001E+06	NO	2	259	427
1804	40	OCCAS.	YES	30	.158579E+06	.212376E+02	.413685E+05	YES		453	607
1805	40	OCCAS.	YES	30	.158579E+06	.212376E+02	.413685E+05	YES		453	607
1806	40	OCCAS.	YES	30	.158579E+06	.198218E+02	.413685E+05	YES		453	607
1807	40	OCCAS.	YES	30	.158579E+06	.198218E+02	.413685E+05	YES		453	607
2002	45	NO	NO		.137895E+06	.278449E+02	.131000E+06	YES		262	566
2101	25	YES	NO		.206843E+06	.330363E+02	.827371E+05	YES		204	522
2102	25	YES	NO		.206843E+06	.330363E+02	.827371E+05	YES		192	518
2103	40	YES	NO		.206843E+06	.566336E+02	.103421E+06	YES		215	488
2201	45	NO	YES	30	.193053E+06	.283168E+02	.103421E+06	YES		268	517
2202	45	NO	YES	30	.193053E+06	.283168E+02	.103421E+06	YES		293	508
2203	45	NO	YES	30	.199948E+06	.330363E+02	.103421E+06	YES		231	454
2204	45	NO	YES	30	.199948E+06	.330363E+02	.103421E+06	YES		272	499
2205	65	NO	YES	45	.206843E+06	.495544E+02	.103421E+06	YES		265	452
2206	65	NO	YES	45	.193053E+06	.401155E+02	.103421E+06	YES		274	429

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2207	55	NO	YES	45	.206843E+06	.471947E+02	.103421E+06	YES		255	425
2208	45	NO	YES	45	.206843E+06	.471947E+02	.103421E+06	YES		265	453
2301	30	YES			.186158E+06	.401155E+02	.827371E+05	YES		249	508
2302	30	YES	NO		.172369E+06	.259571E+02	.827371E+05	YES		238	530
2303											
2304	30	OCCAS.	NO		.151685E+06	.264298E+02	.103421E+06	YES		181	544
2501	45	YES	NO		.172369E+06	.495544E+02	.827371E+05	YES		354	612
2502	60	OCCAS.	NO		.124106E+06	.462508E+02	.689476E+05	YES		311	555
2503	45	OCCAS.	NO		.241316E+06	.637128E+02	.131000E+06	YES	2	260	508
2504	40	OCCAS.	NO		.124106E+06	.401155E+02	.413685E+05	YES		358	653
2505	60	OCCAS.	NO		.172369E+06	.495544E+02	.689476E+05	YES		285	573
2506	45	OCCAS.	NO		.117211E+06	.353960E+02	.689476E+05	YES		326	612
2512	45	YES	NO		.186158E+06	.448350E+02	.151685E+06	YES		272	476
2514	45	YES	NO		.193053E+06	.566336E+02	.151685E+06	YES		272	544
2601	55	OCCAS.	YES	40	.172369E+06	.353960E+02	.689476E+05	YES		283	487
2602	55	OCCAS.	NO	40	.172369E+06	.353960E+02	.689476E+05	YES		283	487
2603	55	OCCAS.	YES	40	.172369E+06	.353960E+02	.689476E+05	YES		283	487
2604	65	OCCAS.	YES	45	.206843E+06	.424752E+02	.689476E+05	YES		283	487
2701	45	OCCAS.	NO		.172369E+06	.377558E+02	.110316E+06	YES		408	561
2801	50	NO	NO		.158579E+06	.519142E+02	.158579E+06	NO	8	312	555
2802	50	NO	NO		.158579E+06	.519142E+02	.158579E+06	NO	8	317	555
2901	45	OCCAS.	NO		.193053E+06	.448350E+02	.689476E+05	YES		272	521
2902	45	OCCAS.	NO		.206843E+06	.471947E+02	.689476E+05	YES		272	521
2907	45	YES	NO		.172369E+06	.453069E+02	.344738E+05	YES		272	512
2908	45	YES	NO		.172369E+06	.401155E+02	.344738E+05	YES		272	521
2909	45	YES	NO		.172369E+06	.401155E+02	.344738E+05	YES		272	498
2910	45	YES	NO		.172369E+06	.401155E+02	.344738E+05	YES		272	464
2911	25	YES	YES	15	.110316E+06	.184059E+02	.344738E+05	YES		371	703
2912	25	YES	YES	15	.124106E+06	.179340E+02	.344738E+05	YES		381	725
2913	25	YES	YES	15	.151685E+06	.273729E+02	.344738E+05	YES		419	703
3001	60	NO	YES	75	.206843E+06	.585214E+02	.344738E+05	YES		342	599
3002	50	YES	YES	20	.165474E+06	.448350E+02	.689476E+05	YES		364	615
3003	50	YES	YES	20	.165474E+06	.424752E+02	.689476E+05	YES		381	691
3008	51	YES	YES	75	.206843E+06	.542739E+02	.344738E+05	YES		365	674
3009	60	YES	YES	75	.165474E+06	.448350E+02	.344738E+05	YES		341	602
3010	60	YES	YES	75	.206843E+06	.542739E+02	.344738E+05	YES		366	628
3011	60	YES	YES	75	.186158E+06	.542739E+02	.344738E+05	YES		379	662
3014	60	YES	NO		.124106E+06	.259571E+02	.482633E+05	YES			
3015	60	YES	NO		.172369E+06	.405874E+02	.482633E+05	YES		258	535
3016	60	OCCAS.	NO		.227527E+06	.566336E+02	.827371E+05	YES		272	512
3017	55	YES	NO		.193053E+06	.283168E+02	.344738E+05	YES		415	681
3018	90	YES	NO		.227527E+06	.471947E+02	.344738E+05	YES		359	672
3201	30	NO	YES	20	.131000E+06	.273729E+02	.413685E+05	YES		272	535
3301	40	NO	NO		.186158E+06	.495544E+02	.186158E+06	YES		249	482
3302	40	NO	NO		.186158E+06	.495544E+02	.186158E+06	YES		249	480
3303	40	NO	NO		.186158E+06	.495544E+02	.186158E+06	YES		249	480

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3304	40	NO	NO		.206843E+06	.471947E+02	.689476E+05	YES		309	566
3305	30	NO	NO		.234422E+06	.509703E+02	.689476E+05	NO	3	300	544
3306	40	NO	NO		.199948E+06	.471947E+02	.689476E+05	NO	3	299	536
3308	40	NO	NO		.137895E+06	.377558E+02	.689476E+05	YES		301	542
3309	40	NO	NO		.124106E+06	.330363E+02	.620528E+05	YES		332	618
3310	45	OCCAS.	YES	60	.206843E+06	.542739E+02	.165474E+06	YES		294	596
3311	45	OCCAS.	YES	60	.227527E+06	.471947E+02	.172369E+06	YES		265	562
3312	40	OCCAS.	YES	60	.165474E+06	.302046E+02	.151685E+06	YES		303	598
3313	40	OCCAS.	YES	60	.179264E+06	.287888E+02	.158579E+06	YES		351	537
3315	45	OCCAS.	YES	60	.110316E+06	.259571E+02	.103421E+06	YES		317	680
3316	45	OCCAS.	YES	30	.137895E+06	.353960E+02	.103421E+06	YES		317	589
3317	45	OCCAS.	YES	30	.172369E+06	.424752E+02	.137895E+06	YES		317	644
3318	45	OCCAS.			.193053E+06	.613531E+02	.103421E+06	NO	11	317	539
3320	50	NO	NO	35	.186158E+06	.401155E+02	.124106E+06	YES		303	525
3321	50	NO	NO	35	.186158E+06	.401155E+02	.124106E+06	YES		332	557
3322	50	NO	NO	35	.179264E+06	.339802E+02	.827371E+05	YES			
3323	50	NO	NO	35	.193053E+06	.339802E+02	.124106E+06	YES		316	639
3324	40	YES	NO		.110316E+06	.259010E+02	.965266E+05	YES		255	575
3325	40	YES	NO		.179264E+06	.495544E+02	.165474E+06	YES		207	483
3326	40	YES	NO		.103421E+06	.259571E+02	.965266E+05	YES		355	533
3327	40	YES	NO		.151685E+06	.415313E+02	.137895E+06	YES		250	644
3328	40	YES	NO		.144790E+06	.363399E+02	.131000E+06	YES			
3329	40	YES	NO		.151685E+06	.410594E+02	.137895E+06	YES		239	523
3330	40	YES	NO		.103421E+06	.306765E+02	.965266E+05	YES		353	604
3331	40	YES	NO		.144790E+06	.410594E+02	.131000E+06	YES		254	581
3332	40	YES	NO		.110316E+06	.377558E+02	.965266E+05	YES		272	576
3333	40	YES	NO		.117211E+06	.363399E+02	.103421E+06	YES		284	571
3334	110	OCCAS.	NO		.337843E+26	.115627E+03	.337843E+06	NO	30	238	539
3335	35	YES	YES	20	.124106E+06	.283169E+02	.482633E+05	YES		529	796
3336	90	NO	NO		.255106E+06	.802310E+02	.103421E+26	NO	20	296	591
3337	60	YES	NO		.144790E+05	.382277E+02	.689476E+05	YES		346	556
3338	75	NO	NO		.179264E+06	.481386E+02	.103421E+06	YES		342	636
3344	45	YES	YES	120	.179264E+06		.344738E+05	YES		326	498
3345	45	YES	YES	180	.179264E+06		.344738E+05	YES		324	521
3346											
3347	60	YES	YES	20	.137895E+06	.212376E+02	.413685E+05	YES		256	635
3348	60	YES	YES	20	.137895E+06	.212376E+02	.413685E+05	YES		256	680
3349	60	YES	YES	20	.206843E+06	.212376E+02	.413685E+05	YES		256	612
3350	75	YES	YES	25	.172369E+06	.302046E+02	.827371E+05	YES		233	565
3351	75	YES	YES	25	.172369E+06	.302046E+02	.827371E+05	YES		233	493
3352	90	YES	YES	35	.206843E+06	.443630E+02	.103421E+06	YES		224	544
3356	60	OCCAS.	YES	45	.165474E+06	.306765E+02	.151685E+06	YES		340	725
3357	55	YES	NO		.137895E+06	.306765E+02	.689476E+05	YES		309	608
3358	55	YES	NO		.124106E+06	.306765E+02	.689475E+05	YES		337	647
3359	70	NO	NO		.172369E+06	.542739E+02	.103421E+06	YES		311	547
3360	70	YES	NO		.165474E+06	.495544E+02	.103421E+06	YES		288	559

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3361	55	YES	NO		.124106E+06	.306765E+02	.689476E+05	YES		329	610
3409	40	YES	YES	20	.137895E+06	.306765E+02	.344738E+05	YES		327	620
3410	40	YES	YES	20	.137895E+06	.306765E+02	.344738E+05	YES		307	671
3411	40	YES	YES	20	.172369E+06	.353960E+02	.344738E+05	YES		282	579
3412	40	YES	NO		.193053E+06	.377558E+02	.344738E+05	YES		272	518
3413	45	YES	NO		.193053E+06	.519142E+02	.827371E+05	NO		320	597
3414	40	YES	NO		.165474E+06	.306765E+02	.275790E+05	YES		328	502
3415	50	YES	NO		.206843E+06	.519142E+02	.124106E+06	YES		303	486
3416	60	YES	NO		.262001E+06	.755115E+02	.262001E+06	YES		312	485
3501	30	OCCAS.	NO		.137895E+06	.264290E+02	.206843E+05	YES		188	494
3502	40	OCCAS.	NO		.172369E+06	.386996E+02	.206843E+05	YES		194	464
3503	60	OCCAS.	NO		.172369E+06	.528581E+02	.482633E+05	YES		198	490
3504	100	OCCAS.	NO		.248211E+06	.759835E+02	.896318E+05	YES		191	428

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0998	OIL	.378541E-03	CU MET/SEC							60.0	35.0
0999	OIL	.378541E-03	CU MET/SEC							60.0	35.0
1001				51	0.70	0.030	0.70	1.18	1.200	74.0	26.0
1002	TAR	.567812E-03	CU MET/SEC	50	1.05	0.028	0.75	1.03	1.670	7.0	
1003											
1101				50	1.00	0.030	0.65	1.07	1.100	5.0	14.0
1102				50	1.00	0.030	0.65	1.07	1.100	3.0	17.0
1201	NATURAL GAS	.124951E+01	CU MET/SEC	48	1.00	0.025	0.47	0.95	1.620	15.0	28.0
1301				56	1.04	0.031	0.74	0.96	1.600	10.0	32.0
1302	TAR	.378541E-03	CU MET/SEC	55	1.28	0.031	0.76	0.97	1.700	20.0	44.0
1303	TAR	.107253E-02	CU MET/SEC	56	1.35	0.029	0.82	1.01	1.700	9.0	39.0
1304				55	1.60	0.033	0.75	0.92	1.600	15.0	39.0
1401				45	1.50	0.028	0.39	0.98	1.330	72.0	25.0
1402				46	1.47	0.038	0.33	0.97	1.320	62.0	35.0
1403				58	1.10	0.030	0.54	0.97	0.930	20.0	37.0
1404				57	1.20	0.030	0.50	0.95	1.000	20.0	37.0
1405				46	1.50	0.027	0.41	0.96	1.320	62.0	35.0
1406				48	1.36	0.034	0.39	1.00	1.220	62.0	35.0
1407				46	1.40	0.032	0.60	0.99	1.240	40.0	40.0
1408				58	1.05	0.030	0.45	0.97	1.020	15.0	38.0
1409	TAR OR OIL	.157725E-02	CU MET/SEC	58	1.10	0.030	0.47	0.98	1.100	14.0	33.0
1410	TAR OR OIL	.157725E-02	CU MET/SEC	46	1.33	0.027	0.86	0.96	1.040	30.0	40.0
1503	TAR	.107253E-02	CU MET/SEC	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1504	TAR	.107253E-02	CU MET/SEC	57	1.50	0.025	0.90	1.25	1.500	10.0	25.0
1505	TAR	.107253E-02	CU MET/SEC	57	1.50	0.025	0.90	1.25	1.500	10.0	25.0
1506	TAR	.107253E-02	CU MET/SEC	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1507	TAR	.107253E-02	CU MET/SEC	57	1.50	0.025	0.90	1.25	1.500	5.0	25.0
1602				60	1.15	0.021	1.20	1.11	1.550	10.0	38.0
1603				60	1.22	0.027	0.68	1.12	1.560	15.0	31.0
1604				60	1.16	0.027	0.60	1.11	1.590	12.0	34.0
1701	TAR	.285168E-02	CU MET/SEC	60	1.01	0.031	0.82	1.17	1.710		33.0
1702	OIL	.340637E-02	CU MET/SEC	60	0.97	0.031	0.80	1.20	1.650		33.0
1804	TAR	.315451E-03	CU MET/SEC	44	1.42	0.053	0.45	0.88	1.150	45.0	50.0
1805	TAR	.315451E-03	CU MET/SEC	44	1.40	0.053	0.45	0.88	1.150	45.0	50.0
1806	TAR	.315451E-03	CU MET/SEC	44	1.42	0.053	0.45	0.88	1.150	45.0	51.0
1807	TAR	.315451E-03	CU MET/SEC	44	1.40	0.053	0.45	0.88	1.150	46.0	48.0
2002				50	1.60	0.020	0.40	1.00	1.500	31.0	4.0
2101	NATURAL GAS	.103910E+01	CU MET/SEC	51	1.09	0.026	0.75	1.05	1.160	5.0	
2102	NATURAL GAS	.937343E+00	CU MET/SEC	51	1.01	0.028	0.78	1.06	1.250	5.0	
2103	NATURAL GAS	.123165E+01	CU MET/SEC	51	1.08	0.026	0.74	1.06	1.070	5.0	
2201	OIL	.189271E-02	CU MET/SEC	51	1.40	0.017	0.79	1.23	1.940	16.0	23.0
2202	OIL	.189271E-02	CU MET/SEC	51	1.24	0.026	0.72	1.23	1.840	0.0	23.0
2203	OIL	.189271E-02	CU MET/SEC	51	1.19	0.026	0.91	1.26	1.960	0.0	19.0
2204	OIL	.176653E-02	CU MET/SEC	51	1.12	0.034	0.78	1.25	1.960	0.0	18.0
2205	OIL	.302833E-02	CU MET/SEC	51	1.15	0.020	0.74	1.28	2.000	0.0	19.0
2206	OIL	.302833E-02	CU MET/SEC	51	1.69	0.025	0.60	1.24	2.130	0.0	19.0

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2207	TAR	.220816E-02	CU MET/SEC	51	0.91	1.750	0.78	1.19	1.570	0.0	0.0
2208	OIL	.277597E-02	CU MET/SEC	51	0.92	0.034	0.78	1.21	1.750	0.0	0.0
2301	COKE OVEN GAS	.707921E-03	CU MET/SEC	49	1.00	0.030	0.90	1.15	1.700		45.0
2302	OIL	.946353E-03	CU MET/SEC	49	1.75	0.030	0.90	1.13	1.800		30.0
2303											
2304	TAR	.946353E-03	CU MET/SEC	45	3.50	0.027	0.85	0.91	1.950	1.0	
2501	NATURAL GAS	.825908E+00	CU MET/SEC	49	1.20	0.035	0.88	1.08	1.940	30.0	0.0
2502	OIL	.201889E-02	CU MET/SEC	48	1.38	0.026	0.73	1.08	1.950	8.0	62.0
2503	OIL	.189271E-02	CU MET/SEC	48	1.37	0.031	0.72	1.03	2.050	0.0	50.0
2504				48	1.32	0.029	0.68	1.05	1.880	12.0	50.0
2505	OIL	.138798E-02	CU MET/SEC	46	1.32	0.032	0.76	1.03	1.910	11.0	49.0
2506	OIL	.113562E-02	CU MET/SEC	48	1.40	0.029	0.68	1.04	1.960	10.0	48.0
2512	OIL	.164034E-02	CU MET/SEC	50	1.20	0.041	0.70	1.10	1.690	1.0	
2514	OIL	.164034E-02	CU MET/SEC	50	1.20	0.036	0.73	1.09	1.830	5.0	32.0
2601	NATURAL GAS OR OIL	.865237E+00	CU MET/SEC	36	1.20	0.030	0.27	1.12	1.350	27.0	23.0
2602	NATURAL GAS	.865237E+00	CU MET/SEC	36	1.20	0.030	0.25	1.12	1.300	27.0	23.0
2603	NATURAL GAS OR OIL	.865237E+00	CU MET/SEC	36	1.20	0.030	0.25	1.12	1.350	27.0	23.0
2604	NATURAL GAS OR OIL	.983224E+00	CU MET/SEC	48	1.20	0.035	0.25	1.12	1.350	27.0	23.0
2701	NATURAL GAS			57	0.92	0.032	0.36	0.88	1.100	83.0	26.0
2801	NATURAL GAS	.141584E+01	CU MET/SEC	50	0.90	0.019	1.10	1.10	1.100		
2802	NATURAL GAS	.141584E+01	CU MET/SEC	50	1.00	0.017	1.10	1.10	1.100		
2901	OIL	.220816E-02	CU MET/SEC	50	1.00	0.050	0.90	1.00	1.750		33.0
2902	OIL	.220816E-02	CU MET/SEC	50	1.00	0.050	0.90	1.00	1.750		33.0
2907	OIL	.189271E-02	CU MET/SEC	50	1.00	0.025	0.75	1.28	2.250	5.0	33.0
2908	OIL	.208198E-02	CU MET/SEC	50	1.20	0.025	0.75	1.25	2.250	5.0	33.0
2909	OIL	.315451E-02	CU MET/SEC	50	1.20	0.025	0.75	1.25	2.250	5.0	33.0
2910	TAR	.378541E-02	CU MET/SEC	50	1.00	0.025	0.75	1.25	2.250	5.0	33.0
2911				51	2.25	0.025	1.00	1.10	1.800	80.0	
2912				51	2.25	0.025	1.00	1.10	1.750	53.0	
2913				51	2.25	0.025	1.00	1.10	1.750	89.0	
3001	TAR	.177914E-02	CU MET/SEC	45	1.19	0.042	0.57	1.07	1.490	15.0	
3002	TAR	.157725E-02	CU MET/SEC	50	1.42	0.037	0.88	1.02	1.570	33.0	2.0
3003	OIL	.227125E-02	CU MET/SEC	52	1.45	0.034	0.89	1.08	1.800	46.0	1.0
3008				42	1.17	0.035	0.27	1.06	1.510	12.0	
3009	OIL	.473176E-02	CU MET/SEC	42	1.23	0.040	0.28	1.07	1.580	12.6	
3010	TAR OR OIL	.580430E-02	CU MET/SEC	45	1.33	0.024	0.40	1.08	1.590	11.0	
3011	TAR OR OIL	.315451E-03	CU MET/SEC	45	1.24	0.028	0.33	1.07	1.530	11.0	
3014											
3015	OIL	.574121E-02	CU MET/SEC	51	1.28	0.030	0.53	1.19	1.520	15.0	
3016	TAR OR OIL	.157725E-02	CU MET/SEC	44	1.14	0.034	0.88	1.02	1.360		
3017	NATURAL GAS	.377228E+00	CU MET/SEC	54	1.10	0.051	0.48	0.90	1.700	37.0	24.0
3018	NATURAL GAS	.358877E+00	CU MET/SEC	54	1.31	0.046	0.47	0.95	1.900	32.0	22.0
3201				52	1.60	0.028	1.00	1.05	2.000	40.0	
3301	OIL	.252361E-02	CU MET/SEC	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0
3302	OIL	.252361E-02	CU MET/SEC	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0
3303	OIL	.252361E-02	CU MET/SEC	47	0.90	0.030	0.60	1.00	1.800	19.0	58.0

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3304	TAR	.630902E-03	CU MET/SEC	50	1.20	0.025	0.70	1.10	1.750	10.0	60.0
3305	TAR	.630902E-03	CU MET/SEC	50	1.10	0.028	0.80	1.10	1.750	19.0	47.0
3306	TAR	.630902E-03	CU MET/SEC	50	1.50	0.040	0.70	1.00	1.800	19.0	47.0
3308	TAR	.630902E-03	CU MET/SEC	50	1.20	0.025	0.85	1.10	1.700		47.0
3309				50	1.20	0.030	0.80	1.05	1.750	40.0	60.0
3310				52	1.00	0.033	0.90	1.05	1.800	10.0	48.0
3311	TAR	.113562E-02	CU MET/SEC	52	1.05	0.035	0.90	1.05	1.800	10.0	50.0
3312	OIL	.100944E-02	CU MET/SEC	52	1.20	0.030	0.70	1.00	1.950	57.0	38.0
3313	OIL	.100944E-02	CU MET/SEC	52	1.30	0.030	0.50	1.05	1.900	24.0	47.0
3315	OIL	.630902E-03	CU MET/SEC	50	1.00	0.030	0.80	1.08	1.450	40.0	40.0
3316	OIL	.441631E-03	CU MET/SEC	50	1.00	0.030	0.80	1.08	1.750	10.0	60.0
3317	OIL	.946353E-03	CU MET/SEC	50	1.00	0.030	0.80	1.08	1.750	10.0	60.0
3318	OIL	.315451E-02	CU MET/SEC	50	1.00	0.030	0.80	1.10	1.700		50.0
3320	OIL	.630902E-03	CU MET/SEC	46	0.93	0.033	0.86	1.15	1.840	17.0	60.0
3321				46	1.22	0.036	0.99	1.15	1.970	7.0	66.0
3322											
3323				46	1.22	0.023	1.36	1.12	1.590	20.0	80.0
3324				52	1.61	0.031	0.58	1.76	2.100	20.0	48.0
3325	TAR OR OIL	.189271E-02	CU MET/SEC	52	1.32	0.030	0.40	1.71	2.180		47.0
3326					1.19	0.025	0.96	1.42	1.250		
3327	TAR OR OIL	.883263E-03	CU MET/SEC	52	1.50	0.026	0.53	2.00	2.450	20.0	50.0
3328											
3329	TAR OR OIL	.151416E-02	CU MET/SEC	52	1.40	0.027	0.37	1.28	1.620		49.0
3330					1.34	0.063	0.83	1.14	1.560		
3331	TAR OR OIL	.189271E-02	CU MET/SEC	52	1.50	0.032	0.33	1.30	1.720		48.0
3332				52	1.40	0.030	0.43	1.43	1.890	44.0	46.0
3333				52	1.21	0.024	0.72	1.43	1.890	38.0	60.0
3334				53	1.40	0.031	0.42	1.06	1.650		30.0
3335					1.00	0.027	0.65	1.14	1.800	39.0	63.0
3336	OIL	.201889E-02	CU MET/SEC	53	1.20	0.033	0.69	1.14	1.730		22.0
3337	OIL	.757082E-03	CU MET/SEC	53	1.39	0.034	0.89	1.13	1.650	19.0	27.0
3338	OIL	.630902E-03	CU MET/SEC	53	1.31	0.059	0.81	1.13	1.690	5.0	29.0
3344				50	1.00	0.028	0.14	1.14	0.085		11.0
3345				50	1.00	0.032	0.16	1.11	0.860		28.0
3346											
3347				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3348				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3349				42	1.20	0.025	0.30	1.00	1.700	44.0	54.0
3350	TAR			50	1.20	0.025	0.37	1.00	1.400	20.0	80.0
3351	TAR			50	1.20	0.025	0.37	1.00	1.400	20.0	80.0
3352				50	1.20	0.025	0.40	1.00	1.500	36.0	40.0
3356				45	2.00	0.018	1.00	1.15	1.900	93.0	
3357	TAR OR OIL	.946353E-03	CU MET/SEC	50	1.26	0.026	0.89	1.04	1.250	52.0	
3358	TAR OR OIL	.946353E-03	CU MET/SEC	50	1.29	0.029	1.03	1.06	1.320	52.0	
3359	TAR	.630902E-03	CU MET/SEC	50	1.24	0.030	0.77	1.06	1.160	29.0	
3360	TAR	.630902E-03	CU MET/SEC	50	1.16	0.029	0.82	1.06	1.170	29.0	

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3361	TAR OR OIL	.567812E-03	CU MET/SEC	50	1.22	0.027	0.90	1.06	1.230	52.0	
3409	TAR	.757082E-03	CU MET/SEC	50	0.98	0.028	1.02	1.21	2.050	15.0	22.0
3410				48	1.27	0.041	0.85	1.21	2.170	1.0	30.0
3411				49	1.43	0.049	0.85	1.11	2.120		22.0
3412	TAR	.145107E-02	CU MET/SEC	49	1.35	0.034	0.60	1.14	2.090		
3413				41	1.22	0.033	1.03	1.19	1.410		
3414	OIL	.132489E-02	CU MET/SEC	44	1.06	0.029	1.69	1.15	1.170		
3415	OIL	.214507E-02	CU MET/SEC	46	1.10	0.029	1.26	1.23	1.650		
3416	OIL	.145107E-02	CU MET/SEC	46	0.97	0.031	1.22	1.11	1.360		
3501	NATURAL GAS	.714638E+00	CU MET/SEC	53	1.17	0.032	1.52	1.05	1.380	3.0	3.0
3502	GAS OR TAR	.126180E-02	CU MET/SEC	53	1.15	0.032	1.56	1.07	1.440		4.0
3503		.107253E-02	CU MET/SEC	53	1.24	0.035	1.43	1.07	1.420	2.0	6.0
3504	NATURAL GAS	.288609E+01	CU MET/SEC	54	1.09	0.031	1.32	1.06	1.320	2.0	6.0

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0998	5.0					NO						NO	5,146
0999	5.0					NO						NO	5,146
1001		100.0	YES	NO	NO	NO	1,454	3.0	14	20	4	YES	9,698
1002	7.0	87.0	YES	NO	NO	NO	1,504	1.0	1	35	7	NO	12,905
1003			YES	NO	NO	NO	1,504	1.0	1			NO	8,838
1101		81.0	YES	NO	NO	NO	1,526	1.0	3	3	3	NO	18,151
1102		86.0	YES	NO	NO	NO	1,526	1.0			2	NO	8,636
1201	3.0	55.0	YES	NO	NO	NO	1,496	7.0	6		6	YES	16,440
1301	2.0	58.0	NO	NO	NO	NO	1,493	1.0	8	16	16	NO	21,785
1302		36.0	NO	NO	NO	NO	1,493	1.0	8	16	16	NO	15,478
1303	2.0	52.0	NO	NO	NO	NO	1,510	1.0	8	16	16	NO	19,332
1304		46.0	NO	NO	NO	NO	1,510	1.0	8	16	16	NO	13,124
1401			YES	NO	NO	NO	1,565	1.0	3	15	3	NO	14,335
1402			YES	NO	NO	NO	1,565	1.0	3	15	3	NO	13,066
1403		40.0	YES	NO	NO	NO	1,543	1.0	3	20	3	NO	12,694
1404		40.0	YES	NO	NO	NO	1,543	1.0	3	20	3	NO	12,855
1405			YES	NO	NO	NO		1.0	3	10	3	NO	11,983
1406			YES	NO	NO	NO		1.0	3	10	3	NO	11,983
1407		15.0	YES	NO	NO	NO	1,565	1.0	3	20	3	NO	13,529
1408		45.0	YES	NO	NO	NO	1,543	1.0	3	20	3	NO	16,895
1409		50.0	YES	NO	NO	NO	1,543	1.0	4	30	5	NO	30,812
1410		27.0	YES	NO	NO	NO	1,548	1.0	3	20	3	NO	21,334
1503	5.0	65.0	YES	NO	NO	NO	1,482	2.0	16	56	8	NO	10,711
1504	5.0	60.0	YES	NO	NO	NO	1,482	2.0	16	56	8	NO	6,601
1505	5.0	60.0	YES	NO	NO	NO	1,482	2.0	16	56	8	NO	12,077
1506	5.0	65.0	YES	NO	NO	NO	1,482	2.0	16	56	8	NO	10,748
1507	5.0	65.0	YES	NO	NO	NO	1,482	2.0	16	56	8	NO	13,[illegible]43
1602	4.0	49.0	NO	NO	NO	NO	1,537	3.0	24	24		NO	8,831
1603	7.0	47.0	NO	NO	NO	NO	1,537	3.0	8	24		NO	19,036
1604	8.0	46.0	NO	NO	NO	NO	1,537	3.0	8	24		NO	13,[illegible]47
1701	2.0	65.0	YES	YES	YES	NO	1,531	2.0	10	15	7	NO	19,408
1702	2.0	65.0	YES	YES	YES	NO	1,531	2.0	10	15	7	NO	19,807
1804	5.0		YES	NO	NO	NO	1,412	1.0	1	30	15	NO	4,946
1805	5.0		YES	NO	NO	NO	1,412	1.0	1	30	15	NO	5,127
1806	4.0		YES	NO	NO	NO	1,412	1.0		30	15	NO	5,116
1807	6.0		YES	NO	NO	NO	1,412	1.0	1	30	15	NO	5,021
2002	4.0	61.0	YES	NO		NO	1,454	1.0	3	35	5	NO	12,264
2101		95.0	NO	NO		NO	1,482	1.0	3	28	0	NO	11,609
2102		90.0	NO	NO		NO	1,482	1.0	3	28	0	NO	11,609
2103	8.0	88.0	YES	NO		NO	1,482	1.0	3	28	0	NO	20,359
2201		54.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	4,530
2202		75.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	4,105
2203		72.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	6,229
2204		76.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	9,061
2205		79.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	11,326
2206		77.0	YES	NO	NO	NO	1,537	8.0	35	40	40	NO	12,459

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2207	0.0	100.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	10,760
2208	0.0	100.0	YES	NO	NO	NO	1,482	8.0	35	40	40	NO	11,043
2301		55.0	NO	NO	NO	NO	1,521	3.0	24	48	3	NO	13,632
2302		70.0	NO	NO	NO	NO	1,510	3.0	24	48	3	NO	11,439
2303												NO	
2304	1.0	99.0	NO	NO	NO	NO	1,510	1.0	3	20	6	NO	16,792
2501	0.0	70.0	YES	NO	NO	NO	1,496	1.0	1	16	2	NO	11,723
2502		30.0	YES	NO	NO	NO	1,493	1.0		250		NO	14,498
2503	5.0	45.0	YES	YES	YES	NO	1,493	1.0		250	2	NO	14,498
2504	5.0	33.0	YES	NO	NO	YES	1,482	1.0	1	500	6	NO	11,440
2505	0.3	40.0	YES	NO	NO	NO	1,498	1.0		250	3	NO	11,440
2506	5.0	37.0	YES	NO	NO	NO	1,487	1.0		400	6	NO	7,843
2512		94.0	YES	NO	NO	NO	1,498	1.0	4		1	NO	21,723
2514		63.0	YES	YES	YES	NO	1,493	1.0	4		1	NO	22,702
2601	5.0	20.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	9,120
2602	5.0	50.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	9,120
2603	5.0	50.0	YES	NO	NO	OCCAS.						NO	8,652
2604	5.0	50.0	YES	NO	NO	OCCAS.		3.0	18	24	0	NO	11,461
2701	17.0	24.0	YES	NO	NO	NO	1,510	2.0	16		32	NO	17,046
2801	2.0	98.0	YES			NO	1,476	2.0	16	24	24	NO	16,194
2802	2.0	98.0	YES			NO	1,482	2.0	16	24	24	NO	16,194
2901	2.0	65.0	YES	NO	NO	NO	1,398	1.0	2	7	7	NO	4,692
2902	2.0	65.0	YES	NO	NO	NO	1,398	1.0	2	7	7	NO	4,692
2907	7.0	55.0	YES	NO	NO	OCCAS.	1,454	5.0	38	0	8	NO	22,481
2908	7.0	55.0	YES	NO	NO	OCCAS.	1,454	5.0	38	0	8	NO	9,652
2909	7.0	55.0	YES	NO	NO	OCCAS.	1,454	5.0	38	0	8	NO	11,636
2910	7.0	55.0	YES	NO	NO	OCCAS.	1,454	5.0	38	0	8	NO	17,021
2911	12.0	8.0	NO	NO		NO	1,426	1.0	1	35	1	NO	6,111
2912	12.0		NO	NO		NO	1,426	1.0	1	35	1	NO	6,535
2913	11.0		NO	NO		NO	1,426	1.0	1	42	1	NO	9,133
3001	3.0	83.0	YES	NO		NO	1,426	7.0	21	42	21	NO	23,254
3002	4.0	61.0	YES	NO	NO	NO	1,454	1.0	3	6	6	NO	12,376
3003	11.0	42.0	YES	NO	NO	NO	1,454	1.0	3	6	6	NO	10,895
3008		88.0	YES	NO	NO	NO	1,482	2.0	12	30	0	NO	10,025
3009		87.0	YES	NO	NO	NO	1,482	2.0	12	30	0	NO	12,844
3010	10.0	78.0	YES	NO		NO	1,482	2.0	12	30	0	NO	13,733
3011	8.0	81.0	YES	NO		NO	1,482	2.0	12	30	0	NO	13,733
3014			NO	NO	NO	NO		1.0	2	18	1	NO	5,279
3015	7.0	79.0	NO	NO	NO	NO		1.0	2	18	1	NO	10,619
3016	5.0	83.0	YES	NO		NO	1,454	1.0	3		1	NO	15,598
3017		39.0	NO	NO	NO	NO	1,343	1.0	7	35		NO	4,504
3018	3.0	43.0	YES	NO	NO	NO	1,371	1.0	6	30	6		10,777
3201	11.0	49.0	YES	NO	NO	NO	1,498	10.0	60	42	0	NO	9,317
3301	7.0	16.0	YES	NO	NO	NO	1,482	1.0	3	2	2	NO	11,255
3302	7.0	16.0	YES	NO	NO	NO	1,482	1.0	3	2	2	NO	11,163
3303	7.0	16.0	YES	NO	NO	NO	1,482	1.0	3	2	2	NO	11,163

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3304		30.0	YES	NO	NO	NO	1,487	1.0	4	16	4	NO	12,468
3305	6.0	28.0	YES	NO	NO	NO	1,487	1.0	4	18	3	NO	12,468
3306	7.0	28.0	YES	NO	NO	NO	1,493	1.0	4	16	3	NO	24,240
3308	7.0	47.0	YES	NO	NO	NO	1,487	1.0	4	20	5	NO	6,215
3309			YES	NO	NO	NO	1,471	1.0	4	20	4	NO	6,049
3310	3.0	39.0	YES	NO	NO	NO	1,471	2.0	14	35	14	NO	9,691
3311	6.0	34.0	YES	NO	NO	NO	1,471	2.0	14	35	14	NO	9,691
3312	5.0		YES	NO	NO	NO	1,460	2.0	12	30	12	NO	12,782
3313	5.0	24.0	YES	NO	NO	NO	1,460	2.0	12	30	12	NO	12,837
3315		20.0	YES	NO	NO	NO	1,471	1.0	8	8	8	NO	9,884
3316	1.0	29.0	YES	NO	NO	NO	1,471	1.0	8	8	8	NO	10,515
3317	2.0	23.0	YES	NO	NO	NO	1,471	1.0	9	9	9	NO	6,732
3318		50.0	YES	NO	NO	NO	1,471	1.0	11	11	11	NO	26,994
3320	6.0	17.0	YES	NO	NO	NO	1,476	5.0	40	6	3	NO	4,951
3321	10.0	17.0	YES	NO	NO	NO	1,476	5.0	40	6	3	NO	4,997
3322			YES	NO	NO	NO	1,476	5.0	40	6	3	NO	5,222
3323			YES	NO	NO	NO	1,476	5.0	40	6	3	NO	5,693
3324	4.0	28.0	NO	NO	NO	NO	1,479	1.0	3	30	5	NO	4,920
3325	2.0	52.0	YES	NO	NO	NO	1,493	1.0	3	30	5	NO	4,182
3326			NO	NO	NO	NO	1,482	1.0	3	30	5	NO	4,036
3327	2.0	28.0	YES	NO	NO	NO	1,468	1.0	3	30	5	NO	3,893
3328			YES	NO	NO			1.0	3	30	5	NO	4,080
3329		51.0	YES	NO	NO	NO	1,473	1.0	3	30	5	NO	5,685
3330			NO	NO	NO	NO	1,454	1.0	3	30	5	NO	4,312
3331		52.0	YES	NO	NO	NO	1,476	1.0	3	30	5	NO	3,727
3332	10.0		NO	NO	NO	NO	1,454	1.0	3	30	5	NO	4,138
3333	2.0		NO	NO	NO	NO	1,476	1.0	3	30	5	NO	4,138
3334		70.0	YES	NO	NO	NO	1,521	5.0	30	90	30	YES	42,227
3335	3.0		YES	NO	NO	NO	1,482	1.0	1	60	30	NO	15,565
3336		78.0	YES	NO	NO	NO	1,482	2.0	20	20	20	NO	7,598
3337	1.0	54.0	YES	NO	NO	NO	1,482	1.0	6	20	6	NO	7,857
3338	1.0	65.0	YES	NO	NO	NO	1,482	1.0	6	20	6	NO	7,857
3344	1.0	89.0	YES	NO	NO	NO	1,454	1.0	2	40	25	NO	13,307
3345	1.0	72.0	NO	NO	NO	NO	1,454	1.0	2	40	25	NO	15,769
3346												NO	15,769
3347	2.0		NO	NO	NO	OCCAS.	1,468	1.0	5	19	3	NO	13,560
3348	2.0		NO	NO	NO	OCCAS.	1,469	1.0	5	19	3	NO	13,560
3349	2.0		NO	NO	NO	OCCAS.	1,469	1.0	5	19	3	NO	13,705
3350			NO	NO	NO	OCCAS.	1,482	1.0	5	6	3	NO	11,880
3351			NO	NO	NO	OCCAS.	1,482	1.0	5	6	3	NO	9,797
3352		30.0		NO	NO	OCCAS.	1,482	1.0	5	6	3	NO	17,839
3356	7.0		YES	NO	NO	NO	1,496	1.0	1	30	18	NO	16,167
3357	3.0	45.0	NO	NO	NO	NO	1,498	1.0	9	56	8	NO	6,535
3358	3.0	45.0	NO	NO	NO	NO	1,482	1.0	9	56	8	NO	6,525
3359	3.0	68.0	NO	NO	NO	NO	1,487	1.0	9	56	8	NO	10,631
3360	3.0	68.0	NO	NO	NO	NO	1,493	1.0	9	56	8	NO	10,608

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FEBRUARY 21,1977
SI UNITS

BLAST FURNACE CODE	SCRAP IN METAL BURDEN (%)	PELLETS IN METAL BURDEN (%)	COKE SCREENED AT STOCK HOUSE?	ORE SCREENED AT STOCK HOUSE?	SINTER SCREENED AT STOCK HOUSE?	LARGE QUAN OF COKE ASSOC W/ CAST?	HOT METAL TEMP (DEG C)	FREQ IRON RUNNER REMAKE (DAYS)	NO. OF CASTS BETWEEN RUNNER RELINE	NO. OF CASTS BETWEEN MAJOR TROUGH REPAIR	NO. OF CASTS BETWEEN NOMINAL TROUGH REPAIR	TILTING SPOUTS USED?	CAST HOUSE VOLUME (CU MET)
3361	3.0	45.0	NO	NO	NO	NO	1,482	1.0	9	56	8	NO	6,515
3409		49.0	NO	NO	NO	NO		1.0	1	60	6	NO	10,194
3410	7.0	63.0	NO	NO	NO	NO		1.0	1	60	6	NO	10,194
3411	1.0	66.0	NO	NO	NO	NO		1.0	1	60	6	NO	9,910
3412	1.0	94.0	NO	NO	NO	NO		1.0	1	75	8	NO	13,875
3413		91.0	YES	NO	NO	NO	1,482	1.0	7	14	10	NO	8,636
3414		84.0	YES	NO	NO	NO	1,482	1.0	7	14	10	NO	7,079
3415		83.0	YES	NO	NO	NO	1,482	1.0	7	14	10	NO	12,742
3416		87.0	YES	NO	NO	NO	1,482	1.0	9	8	6	NO	22,370
3501	7.0	87.0	YES	NO	NO	NO	1,468	5.0	40	40	24	NO	11,497
3502	6.0	87.0	YES	NO	NO	NO	1,468	4.0	40	32	16	NO	8,025
3503	7.0	86.0	YES	NO	NO	NO	1,468	4.0	40	32	16	NO	34,756
3504	7.0	86.0	YES	YES	NO	NO	1,482	5.0	25	25	15	NO	27,880

BLAST FURNACE DATA SHEET

Date of Survey ____________

1. Company's Identification of Furnace ____________
2. Furnace Working Volume, cu. ft. ____________
3. Record Daily Production of Hot Metal, Tons ____________
4. Current Daily Production of Hot Metal, Tons ____________
5. Number of Casts Per Day ____________
6. Hearth Diameter, Feet & Inches ____________
7. Iron Notch Drill Bit Size, Inches ____________
8. Number of Iron Notches ____________
9. Number of Cinder Notches ____________
10. Iron Trough (Pool) Length as made up for cast, ft. ____________
11. Iron Trough (Pool) Width as made up for cast, in. ____________
12. Iron Trough (Pool) Depth as made up for cast, in. ____________

CURRENT AVERAGE OPERATING STATISTICS AND PRACTICES

13. Duration of Cast, Minutes ____________
14. Is O_2 Used to Open Tap Hole? ____________
15. Is Flushing Routinely Accomplished at Cinder Notch? ____________
16. Duration of Flushing, Minutes ____________
17. Normal Blast Pressure at Beginning of Cast, psig ____________
18. Normal Blast Volume at Beginning of Cast, SCFM ____________

19. Normal Blast Pressure when Tap Hole is Stopped, PSIG __________

20. Is Trough Normally Drained After Each Cast? __________

21. If No, How Many Casts Between Draining __________

AVERAGE MATERIAL VALUES

22. Slag Per Ton of Hot Metal, Lbs. __________

23. Coke Per Ton of Hot Metal, Lbs. __________

24. Fuel Used at Tuyeres __________

25. Amount of Fuel at Tuyeres __________

26. Coke Quality, ASTM Stability __________

27. Silicon Content of Hot Metal, % __________

28. Sulfur Content of Hot Metal, % __________

29. Manganese Content of Hot Metal, % __________

30. Slag Basicity, B/A __________

31. Sulfur Content of Slag, % __________

32. Ore in Metallic Burden, % __________

33. Sinter in Metallic Burden, % __________

34. Scrap in Metallic Burden, % __________

35. Pellets in Burden, % __________

36. Is Coke Screened in Stock House? __________

37. Is Ore Screened in Stock House? __________

38. Is Sinter Screened in Stock House? __________

39. Are Large Quantities of Coke Associated with Cast? __________

40. Hot Metal Temperature, °F. __________

TROUGH AND RUNNER MAINTENANCE

41. Frequency of Iron Runner Remaking, Days ____________

42. Material Used to Line Iron Runners ____________

43. Number of Casts Before Relining Runners ____________

44. Number of Casts Between Major Trough Repairs ____________

45. Number of Casts Between Nominal Trough Patching ____________

46. Material Used to Line Trough ____________

CAST HOUSE PHYSICAL DATA

47. Age of Cast House ____________

48. Are Tilting Spouts Used? ____________

49. Width of Cast House, Column to Column ____________

50. Length of Cast House, Centerline Furnace to End Column ____________

51. Distance from Centerline Furnace to Column Line at Rear of Cast House ____________

52. Height from Floor to Bottom of Trusses ____________

53. Height of Sloping Roof, Bottom of Trusses to Monitor ____________

54. Attach Rough Sketch of Cast House Plan, if Possible ____________

55. Please Attach any Plan Drawings of Cast House that are Available ____________

B. ENGINEERING DATA

TABLE NO. B-1

METRIC CONVERSION GUIDE
SI-INTERNATIONAL SYSTEM OF UNITS

Quantity	SI	English Unit	Conversion To Metric (Multiply By)	Remarks
length	metre	foot	3.048 E-01	
area	metre^2	foot^2	9.290 E-02	
density	kilogram/metre^3	lb./ft^3	1.601 E+01	
power	watt	watt	-	
pressure	pascal	psi	6.895 E+03	
energy		inch of H_2O	2.488 E+02	
	joule	BTU	1.055 E+03	
volume	metre^3	ft^3	2.831 E-02	
electrical	metre^3/second	foot^3/minute	4.719 E-04	
	joule	kilowatt-hour	3.600 E+06	
mass	kilogram	ton (2000 lb)	9.071 E+02	
		grain	6.479 E-05	
temperature	°Celsius	Fahrenheit	(°F-32)/1.8	Note: 1°Kelvin = 1°Celsiu
length	metre	micron	1.000 E+06	
weight	Kilogram	Metric ton	1.000 E+03	
pressure	pascal	inches of water	2.488 E+02	
velocity	metre/second	feet/minute	5.080 E-03	
volume/time	metre^3/second	feet^3/minute	4.719 E-04	
volume/time	metre^3/second	gal./minute	6.309 E-05	
acceleration	metre/second^2	foot/second^2	3.048 E-01	
mass/volume	kilogram/metre^3	Grains/DSCF	2.2871 E-03	
mass/mass	kilogram/tonne H.M.	lb/ton HM	5.001 E-01	

AIR FLOW CALCULATIONS
FOR TAP HOLE AND IRON TROUGH CURTAIN ENCLOSURE

HEAT TRANSFERRED TO AIR IN CURTAIN ENCLOSURE:

A. Heat Transfer From Hot Metal Pool Area By Convection During Casting --

$$
\begin{aligned}
h &= 0.38 \times \Delta t^{\frac{1}{4}} \\
&= 0.38 \times (2700 - 130)^{\frac{1}{4}} \\
&= 2.70 \text{ BTU/HR/FT}^2/^{\circ}\text{F}
\end{aligned}
$$

$$
\begin{aligned}
Q_1 &= h \times A \times \Delta T \\
&= 2.70 \times 100 \times (1700 - 130) \\
&= 693900 \text{ BTU/HR}
\end{aligned}
$$

B. Heat Radiated From Hot Metal Pool During Casting --

$$
\begin{aligned}
Q_2 &= 0.173 \times A \times \left(\frac{T}{100}\right)^4 \times e_c \\
&= 0.173 \times 100 \times \left(\frac{3160}{100}\right)^4 \times 0.3 \\
&= 5{,}175{,}063 \text{ BTU/HR}
\end{aligned}
$$

C. Heat Transfer From Furnace Shell By Convection --

$$
\begin{aligned}
h &= 0.30 \times \left(\frac{t}{H}\right)^{\frac{1}{4}} \\
&= 0.30 \times \left(\frac{600 - 130}{37}\right)^{\frac{1}{4}} \\
&= 0.566 \text{ BTU/HR/FT}^2/^{\circ}\text{F}
\end{aligned}
$$

$$
\begin{aligned}
Q_3 &= h \times A \times \Delta t \\
&= 0.566 \times 555 \times (600-130) \\
&= 147{,}641
\end{aligned}
$$

D. Heat Radiated From Furnace Shell --

$$
\begin{aligned}
Q_4 &= 0.173 \times A \times \left(\frac{T}{100}\right)^4 \times e_b \\
&= 0.173 \times 555 \times \left(\frac{460 + 600}{100}\right)^4 \times 0.90 \\
&= 1{,}090{,}950 \text{ BTU/HR}
\end{aligned}
$$

E. Heat Transfer From Bustle Pipe --

$$h = 0.42 \left(\frac{\Delta t}{d}\right)^{1/4}$$

$$= 0.42 \left(\frac{600-130}{72}\right)^{1/4}$$

$$= 0.671 \text{ BTU/HR/FT}^2/^\circ\text{F}$$

$$= h \times A \times \Delta t$$

$$= 0.671 \times 283 \times (600-130)$$

$$= 89{,}249 \text{ BTU/HR}$$

F. Heat Radiated From Bustle Pipe

$$Q_6 = 0.173 \times A \times \left(\frac{T}{100}\right)^4 \times e_6$$

$$= 0.173 \times 283 \times \left(\frac{600 + 460}{100}\right)^4 \times 0.90$$

$$= 556286 \text{ BTU/HR}$$

G. Total Heat Transferred to Air Within Curtain Enclosure --

$$A + B + C + D + E + F = Q_T$$

$$Q_T = 7{,}753{,}089$$

H. Face Area Below and Around Curtain Enclsoure Affected by Air Currents --

Below Curtain (below bustle pipe)

8 x 15 + 2(8 x 32) = 632 sq. ft.

Above Bustle Pipe (between curtain and furnace - below trusses)

(12 x 7) 2 = 84 sq. ft.

Total Face Area = 716 sq. ft.

I. Assumed face velocity necessary to prevent interruption of air flow by cast house cross-currents: 250 feet per minute*

J. Total Required Flow to Enclosure = 250 x 716 x 60 =

1074×10^4 cubic ft./hr.
or 179,000 ACFM @ 130°F

K. 1074×10^4 Cu. Ft./Hr. at 130°F = $1074 \times 10^4 \times .0673$ = 722800 lbs./hour

L. Temperature Inside Enclosure Due To Heat Transfer --

$$Q_T = W_c \times C_p \times \Delta t$$

$$Q_t = W_c \times .241 \times (t_2 - t_1)$$

$$t_2 = \frac{Q_t}{W_c \times .241} + t_1$$

$$t_2 = \frac{7753089}{722{,}800 \times .241} + 130^\circ$$

$$t_2 = 44^\circ + 130^\circ$$

$$t_2 = 174\ ^\circ F$$

M. $1074 \times 10^4 \text{ CFH} \times \frac{460 + 174}{460 + 130} = 1154 \times 10^4 \text{ CFH}$

1154×10^4 CFH = 192,349 ACFM at 174°F

$192349 \times \frac{530}{634} = 160796$ SCFM

N. Area Inside Curtain at Bustle Pipe = 375 sq. ft.

$\frac{192349}{375}$ = 513 FPM at Bustle Pipe

O. Take-Off Duct Diameter = 7 ft.

P. Take-Off Duct Velocity - 4998 FPM

---

* Depending upon the cross-currents present in the cast house this face velocity may not be sufficient and may need to be increased.

h = Local Individual Coefficient of Heat Transfer, BTU/Hr./sq. ft./^{o}F

t = Temperature of air, ^{o}F

A = Area of Heat Transfer Surface, Sq. Ft.

T = Temperature of Surface of Body, ^{o}R

W_c = Weight of Flow of Air, Lb./Hr.

d_e = Density, Lb/cu. ft.

V = Velocity, Ft./Min.

e = Emissivity Coefficient of Radiation (Dimensionless)

Q_1, Q_2, Q_3, Q_4 = Heat Loads, BTU/Hr.

t = Temperature Difference, ^{o}F

s = Stefan-Boltzmann constant, 0.173×10^{-8} BTU/Sq. Ft-Hr-$^{o}R^4$

e_c = 0.30 For Cast Iron at 2700^{o}F (luminous)

e_b = 0.90 For Blast Furnace Shell

d = diameter of bustle pipe, in

H = Height of Shell Contact in Cast House, Ft.

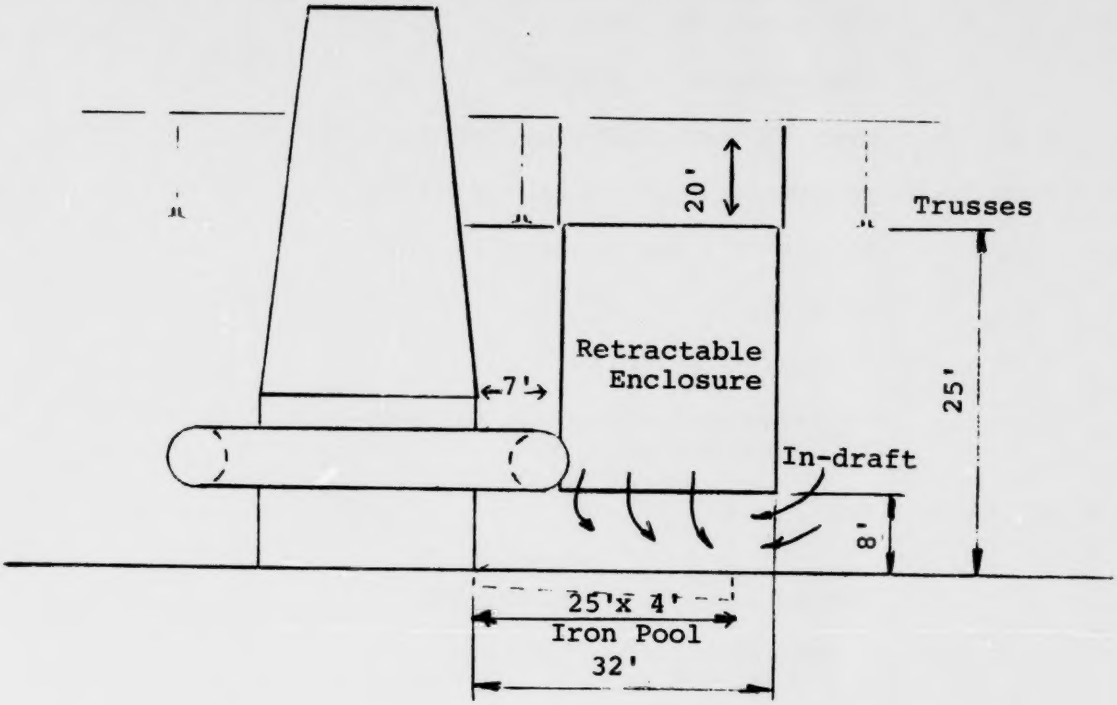
c = Specific Heat of Air, BTU/Lb./^{o}F (0.241 @ 155^{o}f)

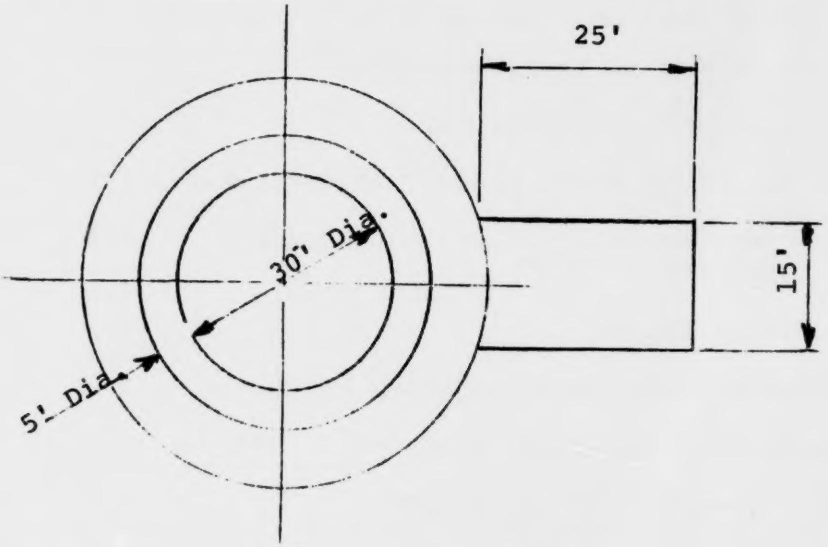
Q_t = Total BTU/HR

References: Chemical Engineers Handbook- Perry

Mechanical Engineers Handbook - Kent

Heat Transfer - C.B. Cramer


20'
Trusses
Retractable
Enclosure
7'
25'
In-draft
8'
25'x 4'
Iron Pool
32'


25'
30' Dia.
15'
5' Dia.

Sample Calculation

The following is a sample calculation for each of the four power house fuel condition curves plotted on figures 5-5, 5-6, and 5-7. The sample calculations use an evacuation rate of 189 m^3/sec. (400,000 cu. ft. per minute) during furnace tapping, casting, and plugging for a total of 7 hours per day. For 17 hours per day when the furnace is melting, the evacuation rate is reduced by 50%. The evacuation rate from any particular cast house should normally never be less than the existing rate of evacuation through the use of natural ventilation with cast house roof monitors.

Basis of Calculations-

1. 1.054E + 07J(10,000 BTU) to produce 1 KW or 100 KW requires 1.054E + 09J(1,000,000 BTU)

2. New Source Standards for Coal Fired Boilers:

   Particulate Matter: 4.5E-02 kg(0.1 lb) per 1.054E + 09J(MMBTU)
   or: 4.5E-04 kg(.001 lb) per KW

   Sulfur Dioxide: 5.4E-01 kg(1.2 lb) per 1.054E + 09J(MMBTU)
   or: 5.4E-03 kg(.012 lb) per KW

   Nitrogen Oxides: 3.2E-01 kg(0.7 lb) per 1.054E + 09J(MMBTU)
   or: 3.2E-03 kg(.007 lb) per KW

3. New Source Standards for Oil Fired Boilers:

   Particulate Matter: 4.5E-02 kg(0.1 lb) per 1.054E + 09J(MMBTU)
   or: 4.5E-04 kg(0.001 lb) per KW

Sulfur Dioxide: 3.6E-01 kg(0.8 lb) per 1.054E + 09J(MMBTU)
or: 3.6E-03 kg(0.008 lb) per KW

Nitrogen Oxides: 1.4E-01 kg(0.3 lb) per 1.054E + 09J(MMBTU)
or: 1.4E-03 kg(0.003 lb) per KW

4. Calculations:

$$\frac{\text{KW-HR}}{\text{Day}} = \frac{QxPxT}{ExF}$$

Where:

$\frac{\text{KW-HR}}{\text{Day}}$ = Kilowatts per day

Q = Volume of air evacuated from cast house, m^3/Sec (CFM)

P = System pressure resistance, Pa("H_2O)

T = Time of operation, hours per day

E = Fan efficiency

F = Conversion Factor 1000 W/KW

5. Assumptions:

1) Air flow = 189 $\frac{m^3}{\text{Sec.}}$ (400,000 CFM) - Avg. cast house volume, 60 air changes per hour, during tapping

2) Air flow - 94.5 $\frac{m^3}{\text{Sec.}}$ (200,000 CFM) - Flow reduced when not tapping

3) Pressure drop, high flow - 3.98 E +03 Pa(16"H_2O), 1.99 E +03 Pa(8"H_2O) across baghouse; 1.99 E+03 Pa(8"H_2O) loss in duct and entry loss

4) Pressure drop low flow = 1.99 E +03 Pa(8"H_2O)

5) Time, high flow - 7 hours per day - Avg. 7 casts per day with Avg. cast duration of 46 min. and 14 min. to get fan to proper flow prior to tap.

6) Fan efficiency, high flow = 0.63 - Typical for radial blade fan at operating point.

7) Fan efficiency, reduced flow = 0.30 typical efficiency at half flow.

6. SI Calculations:

$$\frac{189\ \frac{m^3}{Sec} \times 3984\ Pa \times 7\ Hr/Day}{.63 \times 1000} = 8345\ \frac{KW\text{-}HR}{Day}$$

$$\frac{94.5 \times m^3/Sec \times 1992 \times 17\ Hr/Day}{0.30 \times 1000} = 10635\ \frac{KW\text{-}HR}{Day}$$

$$\overline{18980}\ \frac{KW\text{-}HR}{Day}$$

Power House Fuel - Condition #1

Source: Duquesne Light Company, projected 1986

53.1% coal - .531 x 18980 = 10,078.4
10.0% oil - .100 x 18980 = 1,898.0
36.9% nuclear - .369 x 18980 = 7,003.6
100% 18,980 KWH/Day

Coal

Particulate Matter = 4.5E-04 kg/KW x 10,078.4 KWH/Day = 4.5 kg/Day

SO_2 = 5.4E-03 kg/KW x 10,078.4 KWH/Day = 54.5 kg/Day

NO_x = 3.2E-03 kg/KW x 10,078.4 KWH/Day = 32.3 kg/Day

Oil

Particulate Matter = 4.5E-04 kg/KW x 1,898 KWH/Day = 0.9 kg/Day

SO_2 = 3.6E-03 kg/KW x 1,898 KWH/Day = 6.8 kg/Day

NO_x = 1.4E-03 kg/KW x 1,898 KWH/Day = 2.7 kg/Day

TOTAL =101.7 kg/Day

101.7 kg/Day x 365 Day/Year = 3.7E + 04 kg/yr.

Power House Fuel - Condition #2

100% Coal = 18980 KWH/Day

Particulate Matter = 4.5E-04 kg/KW x 18980 KWH/Day = 8.5 kg/Day

SO_2 = 5.4E-03 kg/KW x 18980 KWH/Day = 102.5 kg/Day

NO_x = 3.2E-03 kg/KW x 18980 KWH/Day = 60.7 kg/Day

TOTAL 171.7 kg/Day

171.7 kg/Day x 365 Day/Year = 6.3E + 04 kg/ yr

Power House Fuel - Condition #3

85% Coal - .85 x 18980 = 16,133
15% Oil - .15 x 18980 = 2,847
100% 18,980 KW/Day

Coal

Particulate Matter = 4.5E-04 kg/KW x 16133 KW/Day = 7.3 kg/Day

SO_2 = 5.4E-03 kg/KW x 16133 KW/Day = 87.1 kg/Day

NO_x = 3.2E-03 kg/KW x 16133 KW/Day = 51.6

Oil

Particulate Matter = 4.5E-04 kg/KW x 2847 KW/Day = 1.3 kg/Day

SO_2 = 3.6E-03 kg/KW x 2847 KW/Day = 10.2 kg/Day

NO_x = 1.4E-03 kg/KW x 2847 KW/Day = 4.0 kg/Day

TOTAL 161.5 kg/Day

161.5 kg/Day x 365 Day/Year = 5.9E + 04 kg/yr

Power House Fuel - Condition #4

Bureau of Mines

51.6% Coal - .516 x 18980 = 9793.7 KWH/Day
18.4% Oil - .814 x 18980 = 3492.3 KWH/Day
30.0% Nuclear- .300 x 18980 = 5694.0 KWH/Day
100% 18980.0 KWH/Day

Coal

Particulate Matter = 4.5E-04 kg/KW x 9793.7 KWH/Day = 4.4 kg/Day

SO_2 = 5.4E-03 kg/KW x 9793.7 KWH/Day = 52.9 kg/Day

NO_x = 3.2E-03 kg/KW x 9793.7 KWH/Day = 31.3 kg/Day

Oil

Particulate Matter = 4.5E-04 kg/KW x 3492.3 KWH/Day = 1.6 kg/Day

SO_2 = 3.6E-03 kg/KW x 3492.3 KWH/Day = 12.6 kg/Day

NO_x = 1.4E-03 kg/KW x 3492.3 KWH/Day = 4.9 kg/Day

TOTAL 107.7 kg/Day

107.7 kg/Day x 365 Day/Year = 3.9E + 04 kg/yr

English Units Calculation

Full Evacuation: $\frac{400{,}000 \times 16 \times 7}{0.63 \times 6356} = 11{,}188$

50% Evacuation: $\frac{200{,}000 \times 8 \times 17}{0.30 \times 6356} = 14{,}265$

Total HP-HR for one day = 25,453

Kilowatt - hours (KWH) = 25,453 x .7457 KWH/HR-HR

KWH/Day = 18980

Power House Fuel - Condition #1

Source: Duquesne Light Company, projected 1986

53.1%	Coal	10,078.4 KWH/Day
10.0%	Oil	1,898.0
36.9%	Nuclear	7,003.6
100%		18,980.0

Coal

Particulate Matter $= .001 \frac{LB}{KWH} \times 10{,}078.4 \frac{KWH}{DAY} = 10.1$

SO_2 $= .012 \frac{LB}{KWH} \times 10{,}078.4 \frac{KWH}{DAY} = 120.9$

NO_x $= .007 \frac{LB}{KWH} \times 10{,}078.4 \frac{KWH}{DAY} = 70.5$

Oil

Particulate Matter $= .001 \frac{LB}{KWH} \times 1{,}898 \frac{KWH}{DAY} = 1.9$

SO_2 $= .008 \frac{LB}{KWH} \times 1{,}898 \frac{KWH}{DAY} = 15.2$

NO_x $= .003 \frac{LB}{KWH} \times 1{,}898 \frac{KWH}{DAY} = \underline{5.7}$

224.3

$$\frac{224.3\ LB/DAY \times 365\ DAY/YEAR}{2{,}000\ LB/TON} = 40.9 \frac{Tons}{YR} \text{ from Power House}$$

Power House Fuel - Condition #2

100% Coal = 18980 KWH/Day

Particulate Matter $= .001 \frac{LB}{KWH} \times 18980 \frac{KWH}{DAY} = 19.0 \frac{LB}{DAY}$

SO_2 $= .012 \frac{LB}{KWH} \times 18980 \frac{KWH}{DAY} = 227.7 \frac{LB}{DAY}$

NO_x $= .007 \frac{LB}{KWH} \times 18980 \frac{KWH}{DAY} = 132.9 \frac{LB}{DAY}$

$379.6 \frac{LB}{DAY}$

$$\frac{379.6\ LB/DAY \times 365\ DAY/YR}{2000\ LB/TON} = 69.3 \frac{Ton}{YR} \text{ from Power House}$$

Power House Fuel - Condition No. 3

$$\begin{array}{llll} 85\% & \text{Coal} - .85 \times 18980 \text{ KWH/Day} = & 16{,}133 & \text{KWH/Day} \\ \underline{15\%} & \text{Oil} \;\; - .15 \times 18980 \text{ KWH/Day} = & \underline{\;\;2{,}847} & \\ 100\% & & 18{,}980 & \text{KWH/Day} \end{array}$$

Coal

Particulate Matter $= .001 \frac{\text{LB}}{\text{KWH}} \times 16{,}133 \frac{\text{KWH}}{\text{DAY}} = 16.1$ LB/Day

SO_2 $= .012 \frac{\text{LB}}{\text{KWH}} \times 16{,}133 \frac{\text{KWH}}{\text{DAY}} = 193.6$ LB/Day

NO_x $= .007 \frac{\text{LB}}{\text{KWH}} \times 16{,}133 \frac{\text{KWH}}{\text{DAY}} = 112.9$ LB/Day

Oil

Particulate Matter $= .001 \frac{\text{LB}}{\text{KWH}} \times 2847 \frac{\text{KWH}}{\text{DAY}} = 2.8$ LB/Day

SO_2 $= .008 \frac{\text{LB}}{\text{KWH}} \times 2847 \frac{\text{KWH}}{\text{DAY}} = 22.8$ LB/Day

NO_x $= .003 \frac{\text{LB}}{\text{KWH}} \times 2847 \frac{\text{KWH}}{\text{DAY}} = \underline{\;\;8.6\;\;}$ LB/Day

TOTAL 356.8 LB/DAY

$$\frac{356.8 \text{ LB/DAY} \times 365 \text{ DAY/YEAR}}{2{,}000 \text{ LB/TON}} = 65.1 \frac{\text{TON}}{\text{YR.}} \text{ from Power House}$$

Power House Fuel - Condition No. 4

Source: Bureau of Mines

$$\begin{array}{llll} 51.6\% & \text{Coal} - .516 \times 18980 \frac{\text{KWH}}{\text{Day}} = & 9793.7 & \text{KWH/Day} \\ 18.4\% & \text{Oil} \;\; - .184 \times 18980 \frac{\text{KWH}}{\text{Day}} = & 3492.3 & \text{KWH/Day} \\ \underline{30.0\%} & \text{Nuclear-} .300 \times 18980 \frac{\text{KWH}}{\text{Day}} = & \underline{5694.0} & \text{KWH/Day} \\ 100.0\% & & 18980 & \text{KWH/Day} \end{array}$$

Coal

Particulate Matter $= .001 \frac{\text{LB}}{\text{KWH}} \times 9793.7 \frac{\text{KWH}}{\text{Day}} = 9.8$ LB/Day

$SO_2 = .012 \frac{\text{LB}}{\text{KWH}} \times 9793.7 \frac{\text{KWH}}{\text{Day}} = 117.5$ LB/Day

$NO_x = .007 \frac{\text{LB}}{\text{KWH}} \times 9793.7 \frac{\text{KWH}}{\text{Day}} = 68.6$ LB/Day

Oil

Particulate Matter $= .001 \frac{\text{LB}}{\text{KWH}} \times 3492.3 \frac{\text{KWH}}{\text{Day}} = 3.5$ LB/Day

$SO_2 = .008 \frac{\text{LB}}{\text{KWH}} \times 3492.3 \frac{\text{KWH}}{\text{Day}} = 27.9$ LB/Day

$NO_x = .003 \frac{\text{LB}}{\text{KWH}} \times 3492.3 \frac{\text{KWH}}{\text{Day}} = \underline{10.5}$ LB/Day

TOTAL 237.8 LB/Day

$$\frac{237.8 \text{ LB/DAY} \times 365 \text{ DAY/Year}}{2000 \text{ LB/TON}} = 43.4 \frac{\text{Ton}}{\text{Yr.}} \text{ From Power House}$$

SUMMARY

Condition No.	Emissions From Power House (Tons/Yr)	(Kg/Yr)
1	40.9	3.7E + 04
2	69.3	6.3E + 04
3	65.1	5.9E + 04
4	43.4	3.9E + 04

C. MISC. EMISSION EVALUATION DATA OF THE NO. 1 CAST HOUSE AT DOMINION FOUNDRY AND STEEL COMPANY

Sampling Procedures

Test Station and Traverse Location--

The sampling location was on a platform servicing the bypass stack. The inside diameter, as obtained from drawings and direct measurement, was 84 inches. Due to test considerations, 24 sample points were used: 12 points per each of the two ports.

Gas Flow and Temperature Determinations--

The gas flow rates and temperature profiles were measured by conducting simultaneous velocity and temperature traverses. Gas velocity heads were measured with a calibrated "S" type Pitot tube which was connected to an inclined manometer. A chromel-alumel thermocouple connected to a potentiometer was used to determine the gas temperature.

Moisture Content--

Moisture sampling was conducted concurrently with particulate sampling employing the principles presented in E.P.A. Method Four. Parameters evaluated in order to determine gas stream moisture content were: sample gas volume, sample gas temperature, sample gas pressure, impinger moisture gain, and silica gel moisture gain. Some minor modifications were made to the Method Four train to allow concurrent particulate and moisture content sampling; these modifications involved no deviations from sampling principles. Modifications involved substitution of a glass fiber filter for Pyrex wool as a filtering medium and substitution of a calibrated orifice for a rotameter as a flow metering device.

Sulfur Dioxide Sampling--

Sampling was performed using the principles in Method 6 of the Federal Register and concurrently with the particulate sampling. Specifically, 150 milliliters of 80% isopropyl alcohol was placed in the first impinger and 150 mls of 3% hydrogen peroxide was placed in each of the second and third impingers. Samples were isokinetically withdrawn in order to meet the requirements of Method Five.

Upon completion, the contents of the impingers were measured volumetrically and placed in a sealed sample bottle. The glassware was rinsed with small amounts of distilled water which was added to the sample bottle.

Particulate Sampling--

All sampling procedures and equipment utilized in the test program were those outlined in Method Five of the Federal Register, Volume 36, Number 247, December 23, 1971. The size of the nozzle required to maintain isokinetic sampling was calculated from the results of the initial temperature and velocity traverses through the use of a nomograph. The sampling train utilized a heated stainless steel probe which was maintained at a temperature in excess of 250°F by an internal heating element. A calibrated "S" type Pitot tube and a chromel-alumel thermocouple were clamped to the probe and were used to monitor the gas velocity and temperature at the individual traverse points during the test period. Sampled gas passed through the nozzle and the probe to a glass fiber filter. The filter was housed in a box maintained at a temperature above 250°F attached to the end of the probe. The gas then passed to the impinger train through a length of tygon tubing. The first impinger contained 150 ml of isopropyl alcohol. The second and third impingers contained 150 mls of hydrogen peroxide. The fourth impinger contained approximately 200 grams of coarse silica gel which collected any moisture and/or vapors which had not been captured in the preceeding impingers.

The first, third, and fourth impingers were 500-ml knock-out impingers. The second impinger was a 500 ml Greenburg-Smith impinger. The entire impinger train was immersed in an ice bath at 32°F for all sample runs.

The sample gas was conducted from the impinger train through an umbilical cord to the control console, a Model 2343 RAC Stak Samplr, which contained the following pieces of equipment (listed in the order in which the sample gas passed through them): a main valve; a bypass valve for flow adjustment; an air tight vacuum pump; a calibrated dry gas meter; and a calibrated orifice. The orifice used to maintain isokinetic conditions was equipped with pressure taps which were connected across an inclined manometer. A schematic diagram of the sampling train is depicted on page C-21 of this Appendix.

The sampling train was subjected to a leak check prior to each sample run. The inlet of the filter holder was plugged, and the pump vacuum was held at 15 in. Hg for one minute. In all cases the leakage rate was minimal and did not exceed the maximum allowable leakage rate of 0.02 CFM.

Upon completion of a test, the soiled glass fiber filter was removed from its holder and placed in a plastic Petri dish which was subsequently sealed. The probe and nozzle were rinsed internally with acetone; the particulate matter remaining in the probe was removed with a nylon brush attached to a rifle cleaning rod. The brush was rinsed, and the washings obtained were added to the nozzle and probe washings. The front-half of the filter holder was also rinsed with acetone. All washings were stored in a sealed bottle. The content of the first three impingers were measured volumetrically and then stored in a sealed bottle. The silica gel was removed from the fourth impinger and stored in a sealed polyethylene sample bottle. Samples of the deionized water and all reagents used in the test program were stored in separate bottles to be analyzed as blanks.

Particle Size Analysis - Andersen Method--

The particle size distribution for the particulate matter suspended in the gas stream was determined utilizing an Andersen 2000 Impactor, Model No. 50-001. The gas velocity pressures and the gas temperatures were measured at each point of the sampling program.

The isokinetic nozzle was attached to the inlet of the Andersen head to facilitate the use of the particulate sampling nomograph in the calculation of the isokinetic sampling rate. Sampled gas was drawn through the nozzle at an isokinetic rate to the Andersen head which contained nine separate stainless steel collecting plates. Each plate was perforated with a series of precision drilled orifices arranged in concentric circles which are offset on each succeeding plate. The diameters of all orifices on a given plate were equal, but orifice diameters on subsequent downstream plates decreased in size for each succeeding plate. As the gas sample was drawn through the Andersen head, air jets flowing through a particular plate directed suspended particulates toward the collection area on the downstream plate directly below the orifices on the plate above. The decrease in jet diameter from plate to plate resulted in an increase in gas velocity. A sufficiently large increase in gas velocity resulted in a situation where the inertial forces acting on a particular particles were great enough to overcome the aerodynamic drag of the turning airstream. This situation resulted in the impaction of the particle on the collection surface. An insufficient increase in gas velocity allowed the particular particle to remain in the gas stream, and to undergo another velocity increase as it passed through a jet on the next downstream plate. Therefore, particles of decreasing particle diameter were impacted out on successive plates.

Each plate had been cleaned, dried, desiccated, and tare weighted prior to its insertion into its position in the Andersen head.

Sample gas exiting the Andersen head proceeded through the probe to a glass fiber filter which collected any particulate matter not impacted on a collection plate and then to an impinger train identical to the train described in the "Particulate Sampling Program" section of this Appendix, with the exception that the first two impingers contained water. Gases exiting the fourth impinger were then conducted to the R.A.C., Model 2343, Stak Samplr also described in the same "Particulate Sampling Program" section. Refer to pages C-46 and C-47 of this Appendix for schematic diagrams of both the Andersen head and the sampling train.

Upon completion of the sampling period the entire Andersen head was returned to the laboratory. The probe was rinsed internally with acetone in order to remove any particulate matter which had collected in it during the sampling period. Any particulates remaining in the probe following the acetone washing were removed with a nylon brush attached to a rifle cleaning rod; the probe was then again rinsed internally with acetone. All washings were combined and stored in a sealed polyethylene sample bottle. The soiled glass fiber filter was removed from the filter holder and stored in a sealed plastic Petri dish.

Visible Emissions Observations--

The visible emissions evaluation as reported in Table 5-3 was conducted by a certified opacity observer in the manner prescribed by the UNITED STATES ENVIRONMENTAL PROTECTION AGENCY in its Visible Emissions Evaluation Course. Stack opacity readings were recorded at fifteen (15) second intervals for a one

(1) hour period. Also recorded were pertinent meteorological conditions.

Field Data Sheets

The flue gas velocity head, the flue gas temperature, the inlet and outlet dry gas meter temperatures, the orifice pressure differential, the sample volume, the sampling time, and the pump vacuum were recorded during the entire sampling program. Copies of all field data sheets generated follow.

B-E-E

FIELD DATA SHEET

Cast No. 3475

PLANT DOFASCO (EPA)
DATE 24 August 1976
SAMPLING LOCATION Outlet
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 1-high
OPERATOR RPH
AMBIENT TEMPERATURE 85^0 F
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) C 904
GEL NUMBER(S) C 319

ORSAT:
CO_2
O_2
CO

PROBE NUMBER AND TYPE 10'SS
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 2.01
C FACTOR 1.15
PROBE HEATER SETTING 1.0V AC
HEATER BOX SETTING 250
REFFERENCE Δp 7.3 → 7.8
PITOT C_p AND NO.
L.C OK 0.010 CFM

READ AND RECORD ALL DATA EVERY 3 MINUTES

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	11:37	22.916									
A-12	03	11:40	25.7	6.5	1.67	1.67	130	72	72	7	350	72
A-11	06	11:43	27.7	6.7	1.70	1.70	132	72	72	8	420	72
A-10	09	11:46	29.7	7.0	1.77	1.77	125	77	73	8	450	80
A-9	12	11:49	31.9	7.8	1.97	1.97	139	81	74	9	455	82
A-8	15	11:52	33.9	6.7	1.70	1.70	150	84	75	8	450	83
A-7	18	11:55	35.9	6.0	1.55	1.55	155	86	76	8	455	82
A-6	21	11:58	37.8	5.8	1.40	1.40	152	89	78	8	450	80
A-5	24	12:01	39.5	2.1	0.49	0.49	151	89	80	4	449	78
A-4	27	12:04	41.1	6.3	1.50	1.50	149	89	80	8	451	80
A-3	30	12:07	42.7	5.3	1.25	1.25	140	90	82	7	450	82
A-2	33	12:10	44.2	5.5	1.30	1.30	140	90	82	7.5	455	80
A-1	35	12:13	45.073	5.5	1.30	1.30	140	91	84	8	450	80

B-E-E

FIELD DATA SHEET

Cast No. 3480

PLANT DOFASCO (EPA)
DATE 25 August 1976
SAMPLING LOCATION Bypass Outlet
SAMPLE TYPE Part./SO_2/ SO_3
RUN NUMBER 2-high
OPERATOR RPH
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 2.01
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES L.C. 0.000

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	09:22	47.703									
A-12	03	09:25	49.5	6.0	1.45	1.45	130	79	79	4.5	200	66
A-11	06	09:28	51.5	6.3	1.50	1.50	130	79	79	5	220	66
A-10	09	09:31	53.5	6.5	1.55	1.55	132	83	80	5	225	64
A-9	12	09:34	55.5	7.0	1.65	1.65	130	86	81	5.7	250	64
A-8	15	09:37	57.6	7.5	1.80	1.80	140	89	82	6.7	325	64
A-7	18	09:40	59.5	5.8	1.40	1.40	150	91	82	6	330	64
A-6	21	09:43	61.5	6.3	1.50	1.50	152	93	84	6.5	300	64
A-5	24	09:46	63.5	6.0	1.45	1.45	151	96	86	6.5	285	70
A-4	27	09:49	65.434	5.8	1.40	1.40	145	98	88	6.5	262	70

B-E-E

FIELD DATA SHEET

Cast No. 3481

PLANT DOFASCO (EPA)
DATE 25 August 1976
SAMPLING LOCATION Bypass Outlet
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 3-high
OPERATOR RPH
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:
CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 1.99
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES L.C. 0.019 CFM

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	15:19	66.008									
A-12	03	15:22	68.2	5.0	1.2	1.2	130	79	79	6	305	80
A-11	06	15:25	70.3	7.5	1.8	1.8	125	81	80	7	400	80
A-10	09	15:28	72.5	8.0	1.85	1.85	110	84	80	7.5	395	72
A-9	12	15:31	74.7	8.2	1.90	1.90	110	87	81	8	330	72
A-8	15	15:34	76.9	8.0	1.85	1.85	145	90	82	8	275	76
A-7	18	15:37	79.0	7.5	1.80	1.80	110	93	84	8	250	80
A-6	21	15:40	81.5	6.5	1.55	1.55	120	95	85	7	260	80
A-5	24	15:43	83.0	6.0	1.40	1.40	115	96	87	7	360	80
A-4	27	15:46	84.9	5.5	1.30	1.30	115	97	88	6.7	345	80
A-3	30	15:49	86.8	6.0	1.40	1.40	145	98	90	7	335	80
A-2	33	15:52	88.7	5.5	1.30	1.30	135	99	91	6.7	300	80
A-1	36	15:55	90.6	5.0	1.20	1.20	150	99	92	6.3	300	80
x	44	16:03	95.441	6.0	1.40	1.40	155	100	93	6.5	300	80

B-E-E

FIELD DATA SHEET

Cast No. 3482

PLANT DOFASCO (EPA)
DATE 25 August 1976
SAMPLING LOCATION Bypass Outlet
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 4
OPERATOR FJK
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 10'
NOZZLE I.D. AND NO. .125
ASSUMED MOISTURE, %
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$
C FACTOR
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp 7.8
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\ in}$), °F	OUTLET ($T_{m\ out}$), °F			
	00	18:53	96.220									
A-12	03	18:56	97.5	3.1	.71	.71	140	82	82	3	250	82
A-11	06	18:59	98.8	2.7	.64	.64	142	83	83	3	272	82
A-10	09	19:02	100.1	2.7	.64	.64	150	84	84	3.5	300	81
A-9	12	19:05	101.4	2.7	.64	.64	140	85	84	3.5	380	80
A-8	15	19:08	102.7	2.7	.64	.64	155	86	84	3.5	325	84
A-7	18	19:11	104.1	2.4	.58	.58	153	88	85	3.5	280	80
A-6	21	19:14	105.4	2.7	.54	.64	150	89	85	4	282	80
A-5	24	19:17	106.7	2.7	.64	.64	170	90	86	4	250	80
A-4	27	19:20	108.2	2.7	.64	.64	152	92	87	4	260	80
A-3	30	19:23	109.472	2.7	.64	.64	152	93	89	4	280	82

B-E-E

FIELD DATA SHEET

CAST NO. 3487

PLANT DOFASCO (EPA)
DATE 26 August 1976
SAMPLING LOCATION Bypass Stack
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 5-low
OPERATOR RPH
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 2.01
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp 8.0
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES

L.C. ok (.1)

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	11:22	113.494									
A-12	03	11:25	115.1	3.7	0.88	0.88	125	80	80	4.5	300	75
A-11	06	11:28	116.7	3.7	0.88	0.88	150	81	81	5	322	72
A-10	09	11:31	118.2	3.4	0.81	0.81	152	83	81	5.2	325	70
A-9	12	11:34	119.7	3.4	0.81	0.81	150	85	82	5.5	355	70
A-8	15	11:37	121.3	3.4	0.81	0.81	154	87	83	6	305	68
A-7	18	11:40	122.7	3.1	0.73	0.73	155	89	84	6	300	70
A-6	21	11:43	124.2	3.4	0.81	0.81	150	90	85	6.5	270	70
A-5	24	11:46	125.7	3.1	0.73	0.73	152	91	85	6.3	255	72
A-4	27	11:49	127.1	3.0	0.71	0.71	165	93	87	6.3	250	70
A-3	30	11:52	128.5	3.0	0.71	0.71	165	97	89	6.5	245	69
A-2	33	11:55	129.8	2.6	0.62	0.62	200	99	90	6.3	210	68
A-1	36	11:58	131.162	2.6	0.62	0.62	195	98	91	6.5	225	73

B-E-E

FIELD DATA SHEET

Cast No. 8488

PLANT DOFASCO (EPA)
DATE 26 August 1976
SAMPLING LOCATION Bypass Stack
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 6 Med.
OPERATOR GWB
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 1.99
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp 8.0
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
A-12	00	15:06	131.9 21	6.5	1.6		130	82	83	5	270	80
A-11	03	15:09	134.0	7.2	1.75		148	83	82	5	300	70
A-10	06	15:12	136.0	7.5	1.8		150	85	82	6	270	79
A-9	09	15:15	138.1	7.0	1.7		140	88	83	7	255	80
A-8	12	15:18	off 140.422 off			fan down						
A-7	15	15:22	on 140.422 on	7.5	1.8		153	86	83	7	250	80
A-6	18	15:25	142.4	7.5	1.8		175	89	84	8	220	77
A-5	21	15:28	144.8	7.5	1.8		180	91	85	7	230	77
A-4	24	15:31	146.7	6.3	1.5		185	93	86	8.5	260	77
A-3	27	15:34	148.9	5.7	1.4		170	94	86	9.5	250	77
A-2	30	15:37	off 150.879									

Cast No. 3489

B-E-E

FIELD DATA SHEET

PLANT DOFASCO (EPA)
DATE 26 August 1976
SAMPLING LOCATION Bypass Stack
SAMPLE TYPE Part/SO_3/SO_2
RUN NUMBER 7
OPERATOR RPH
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 1.99
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp 8.0
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES L.C. ok (1.5)

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	18:30	151.117									
A-12	03	18:33	153.2	6.3	1.50	1.50	130	90	90	5.5	305	68
A-11	06	18:36	155.3	6.5	1.57	1.57	138	91	91	6	325	68
A-10	09	18:39	157.5	7.5	1.80	1.80	140	94	91	7	313	72
A-9	12	18:42	159.6	7.2	1.70	1.70	145	96	91	7	320	76
A-8	15	18:45	161.7	7.0	1.67	1.67	130	100	92	7	300	77
A-7	18	18:48	163.7	6.8	1.65	1.65	142	101	94	7	280	77
A-6	21	18:51	166.5	6.5	1.57	1.57	151	102	94	7	250	78
A-5	24	18:54	168.4	5.0	1.20	1.20	146	102	94	6	235	80
A-4	27	18:57	170.3	5.7	1.38	1.38	150	102	95	6.5	230	80
A-3	30	19:00	172.2	5.5	1.30	1.30	155	102	95	6.7	220	80
A-2	33	19:03	174.045	5.5	1.30	1.30	160	102	96	6.7	210	80

B-E-E

FIELD DATA SHEET

Cast No. 3492

PLANT DOFASCO (EPA)
DATE 27 August 1976
SAMPLING LOCATION Bypass Stack
SAMPLE TYPE Part/SO_3/SO_2
RUN NUMBER 8-med.
OPERATOR RPH
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

ORSAT:
CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D. AND NO. 0.122
ASSUMED MOISTURE, % 2.5
SAMPLE BOX NUMBER
METER BOX NUMBER 7
METER $\Delta H_@$ 1.99
C FACTOR 1.15
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp 8.0
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES

L.C. ok (+3)

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\ in}$), °F	OUTLET ($T_{m\ out}$), °F			
	00	08:47	174.300									
A-12	01	08:48		6.8	1.60	1.60	165	78	80	7.5		
	on	09:01										
	03	09:03	176.8	lost	electrical		power					
A-11	06	09:06	178.8	6.5	1.57	1.57	165	81	80	7		
A-10	08	09:08	180.2	6.5	1.57	1.57	172	84	80	7		
A-9	10	09:10	181.5	5.7	1.37	1.37	155	86	81	6.5		
A-8	12	09:12	182.8	6.2	1.50	1.50	142	88	81	6.5		
A-7	14	09:14	184.1	5.9	1.40	1.40	150	89	82	6.3		
A-6	14.5	09:14.30	184.500	5.5	1.32	1.32	154	90	82	6.3		

Cast No. 3493

PLANT DOFASCO (EPA)
DATE 27 August 1976
SAMPLING LOCATION Bypass Stack
SAMPLE TYPE Part./SO_3/SO_2
RUN NUMBER 9
OPERATOR FJK
AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
STATIC PRESSURE, (P_s)
FILTER NUMBER (s)
GEL NUMBER(S)

FIELD DATA SHEET

ORSAT:

CO_2
O_2
CO

PROBE NUMBER AND TYPE 11'
NOZZLE I.D AND NO.
ASSUMED MOISTURE, %
SAMPLE BOX NUMBER
METER BOX NUMBER
METER $\Delta H_@$
C FACTOR
PROBE HEATER SETTING
HEATER BOX SETTING
REFERENCE Δp
PITOT C_p AND NO.

READ AND RECORD ALL DATA EVERY 3 MINUTES

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft³	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	00	12:07	185.2									
A-12	03	12:10	187.1	5.0	1.2	1.2	125	84	84	4	225	82
A-11	06	12:13	189.0	5.3	1.25	1.25	140	86	86	4	230	83
A-10	09	12:16	196.7	5.7	1.4	1.4	140	90	87	4	200	80
A-9	12	12:19										
				Lost Electrical Power								

BETZ ENVIRONMENTAL ENGINEERS, INC.

Date 25 August 1976
Observer G.W. Bainton

Location
Name DOFASCO (EPA)
Address Hamilton, Ontario, Canada

Observation Point Southwest of Stack

Stack - Distance From 100' Height 50'
Wind - Speed 0-5 mph Direction from east
Type of Installation Cast House
Evacuation Bypass Stack
Fuel
Observation began 15:18 Ended 16:01

Density Smoke Tabulation

No. Units	×	Equiv. No. 1 Units
	Units No. 0	
1	Units No. ½	0.50
13	Units No. 3/4	9.75
77	Units No. 1	77.00
50	Units No. 1 1/4	62.50
32	Units No. 1 1/2	48.00
2	Units No. 1 3/4	3.50
1	Units No. 2	2.00
	Units No. 4	
	Units No. 4½	
	Units No. 5	
176	Units	203.25 Equiv. Units

$\frac{\text{Equiv. Units}}{\text{Units}} \times 20\% =$

23.1 % Smoke Density

Remarks: one-half hour observations of bypass stack conducted during cast no. 3481 (test run no. 3-high)

Sky: blue-gray

	0	15	30	45		0	15	30	45
0	20	20	25	20	30	20	20	20	20
1	25	30	30	20	31	20	20	25	25
2	20	30	25	25	32	25	25	25	25
3	30	30	25	20	33	25	25	25	20
4	25	25	30	30	34	25	20	20	25
5	30	30	20	25	35	20	20	25	25
6	30	35	30	25	36	20	20	25	25
7	30	25	25	30	37	25	20	20	20
8	30	20	20	25	38	30	30	30	25
9	30	30	30	20	39	25	30	30	20
10	30	30	20	25	40	30	25	25	25
11	25	20	25	30	41	30	25	30	25
12	30	30	30	30	42	20	20	20	20
13	20	20	20	25	43	20	25	25	25
14	25	20	20	20	44				
15	25	20	20	15	45				
16	15	15	15	20	46				
17	20	20	15	15	47				
18	25	25	25	25	48				
19	20	20	20	20	49				
20	20	20	20	15	50				
21	20	15	20	20	51				
22	20	20	25	20	52				
23	20	20	20	20	53				
24	15	15	20	20	54				
25	20	20	20	20	55				
26	20	35	40	25	56				
27	20	20	20	20	57				
28	20	20	15	10	58				
29	15	15	20	20	59				

Owner Manager DOFASCO
Address Hamilton, Canada

BETZ ENVIRONMENTAL ENGINEERS, Inc.

VELOCITY DETERMINATIONS

Client: DOFASCO (EPA)

Location: Bypass Stack

Date: 23 August 1976

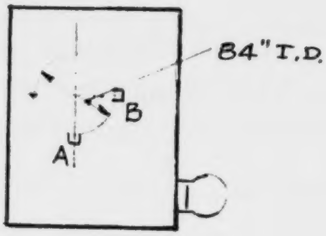
Stack Pressure:

Barometric Pressure:

Pitot Factor: #9.3

Engineer: RPH/FJK

Sample Port Location:



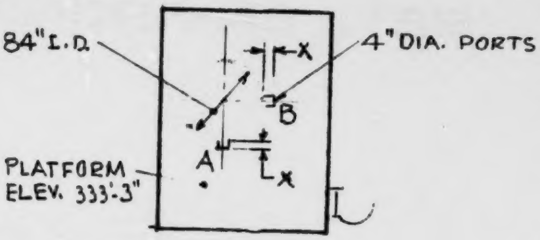
Pitot/Temperature Readings

Point No.	Distance (Inches)	Port A		Port B		Port__		Port__		Port__	
		ΔP	T	ΔP	T	ΔP	T	ΔP	T	ΔP	T
1	4 1/4	6.7	Amb.	6.0	Amb.						
2	8 1/8	6.7		6.3							
3	12 7/16	7.2		6.5							
4	17 3/8	7.5		6.3							
5	23 1/2	7.0		6.8							
6	32 5/16	6.5		6.8							
7	56 11/16	6.0		6.5							
8	65 1/2	6.0		5.7							
9	71 5/8	5.3		6.3							
10	76 9/16	5.8		6.8							
11	80 7/8	5.5		6.0							
12	84 3/4	5.5		5.2							
TOTAL											
AVG.				6.3							

BETZ ENVIRONMENTAL ENGINEERS, INC.

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

PLANT DOFASCO (EPA)
DATE
SAMPLING LOCATION Bypass Stack
INSIDE OF FAR WALL TO OUTSIDE OF NIPPLE. (DISTANCE A)
INSIDE OF NEAR WALL TO OUTSIDE OF NIPPLE. (DISTANCE B)
STACK I.D., (DISTANCE A - DISTANCE B) 84"
NEAREST UPSTREAM DISTURBANCE
NEAREST DOWNSTREAM DISTURBANCE
CALCULATOR RPH



SCHEMATIC OF SAMPLING LOCATION

TRAVERSE POINT NUMBER	FRACTION OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1 8 INCH)	DISTANCE X	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	0.021	84"	1 3/4	2 1/2	4 1/4
2	0.067		5 5/8		8 1/8
3	0.118		9 15/16		12 7/16
4	0.177		14 7/8		17 3/8
5	0.250		21		23 1/2
6	0.355		29 13/16		32 5/16
7	0.645		54 3/16		56 11/16
8	0.750		63		65 1/2
9	0.823		69 1/8		71 5/8
10	0.882		74 1/16		76 9/16
11	0.933		78 3/8		80 7/8
12	0.979		82 1/4		84 3/4

BETZ ENVIRONMENTAL ENGINEERS, Inc.

NOMOGRAPH DATA

PLANT DOFASCO (EPA)

DATE 24 August 1976

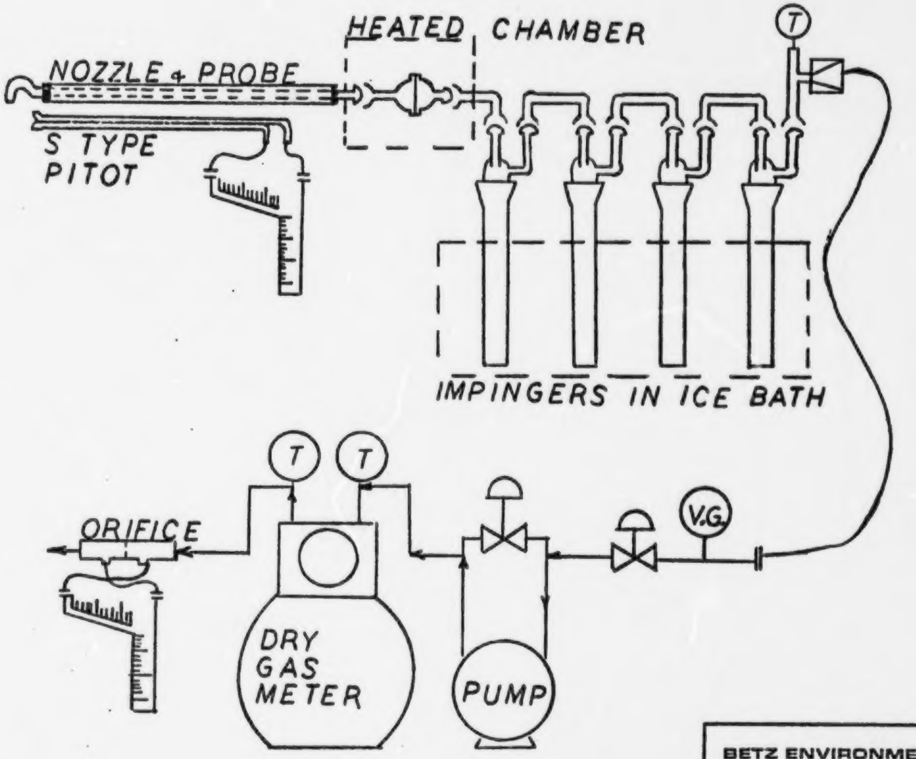
SAMPLING LOCATION Bypass Stack

Particulate System

CALIBRATED PRESSURE DIFFERENTIAL ACROSS ORIFICE, in. H_2O Box 7	$\Delta H_@$	2.01
AVERAGE METER TEMPERATURE (AMBIENT + 20 °F), °F	$T_{m\,avg.}$	95
PERCENT MOISTURE IN GAS STREAM BY VOLUME	B_{wo}	2.5
BAROMETRIC PRESSURE AT METER, in. Hg	P_m	
STATIC PRESSURE IN STACK, in. Hg ($P_m \pm 0.073$ x STACK GAUGE PRESSURE in in. H_2O)	C_p	.832
RATIO OF STATIC PRESSURE TO METER PRESSURE	P_s/P_m	
AVERAGE STACK TEMPERATURE, °F	$T_{s\,avg.}$	110
AVERAGE VELOCITY HEAD, in. H_2O	$\Delta p_{avg.}$ *	4.8
MAXIMUM VELOCITY HEAD, in. H_2O	$\Delta p_{max.}$	-
C FACTOR		1.15
CALCULATED NOZZLE DIAMETER, in.		0.135
ACTUAL NOZZLE DIAMETER, in. Set 3		0.122
REFERENCE Δp, in. H_2O		7.3

EPA (Dur) 234
4/72

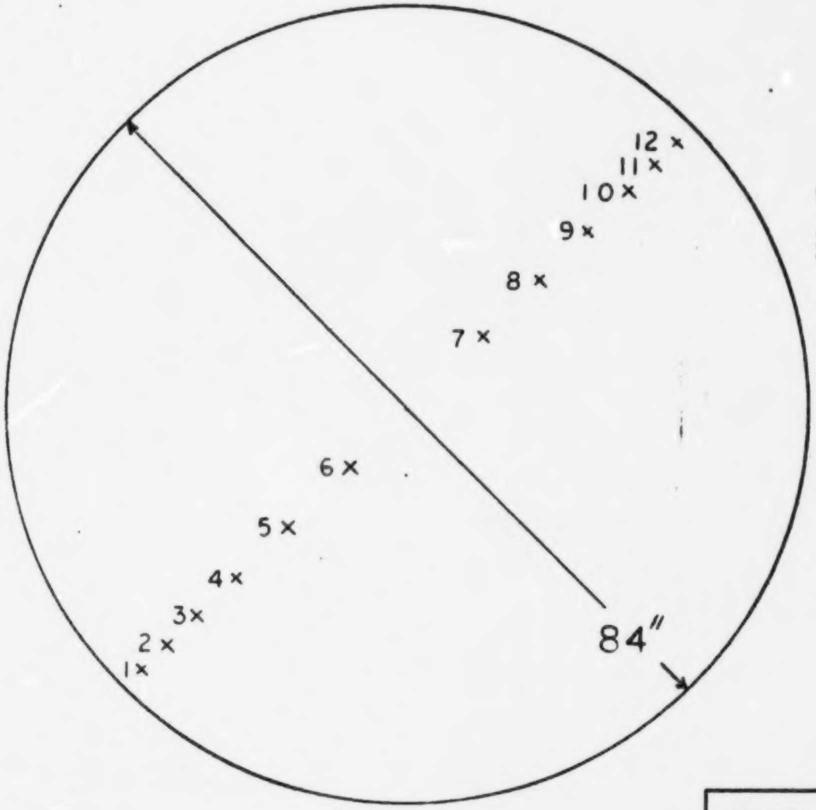
* Estimated from proposed flow rate of 300,000 ACFM from DOFASCO - contact Al Kruzins.


HEATED CHAMBER
T
NOZZLE & PROBE
S TYPE PITOT
IMPINGERS IN ICE BATH
T
T
V.G.
ORIFICE
DRY GAS METER
PUMP

BETZ ENVIRONMENTAL ENGINEERS, Inc.
One Plymouth Meeting Mall • Plymouth Meeting, Pa. 19462

FOR

TITLE MODIFIED PARTICULATE SAMPLING TRAIN
DRAWN BY EJK
DATE 11-10-75
APPROVED BY
DRAW NO
SCALE NONE



POINT	DIST.
1	1 3/4
2	5 5/8
3	9 15/16
4	14 7/8
5	21
6	29 13/16
7	54 3/16
8	63
9	69 1/8
10	74 1/16
11	78 3/8
12	82 1/4

BETZ ENVIRONMENTAL ENGINEERS, Inc.
One Plymouth Meeting Mall • Plymouth Meeting, Pa. 19462
FOR
TITLE STACK DRAWING TOP VIEW
SHOWING SAMPLE POINTS & I.D.
DRAWN BY FJK
DATE 11-10-75
APPROVED BY
DRAW NO
SCALE NONE

STAKSAMPLR CALIBRATION SHEET

Date 20 August 1976 Box No. 7 Inspector

Pump x Pump Serial No.

Pump Oil x

Clean Quick Connects x Valves x

Manometers x

Dry Test Meter changed Meter Serial No.

Thermometers x In °F Out °F Ambient °F

Lights x

Electrical Check - Amphenol x

Variac x

Vacuum Gauge x

Leak Check at 27" Hg.--Leakage x .0.00 CFM

Remarks

Calibration--Orifice and Meter

Date 20 Aug. 1976 Box No. 7 Pb 30.35

Man Orifice	CF_w	CF_d	T_W	IT_d	OT_d	Td Avg.	Time
0.5	5.250	5.400	73	91	83	87	13:29.7
1.0	5	5.091	73	89	81	85	9:14
2.0	10	10.105	73	86	78	82	13:31
4.0	10						
6.0	10						
8.0	10						

Calculate Y & $H_@$ at man. 2.0

$$Y = \frac{CF_w \; P_b \; (T_d \text{ avg.} + 460)}{CF_d \; (P_b + 0.147) \; (T_w + 460)}$$

$$\Delta H_@ = \frac{0.0634}{P_b \; (OT_d + 460)} \left(\frac{(T_w + 460) \; t}{CF_w} \right)^2$$

Tolerances:

Y = 0.99 - 1.00 - 1.01

ΔH = 1.6 - 1.84 - 2.1

CALIBRATION CALCULATIONS METER AND PUMP BOX Date 20 August 1976 Box No. 7

$\frac{0.0317\ (\text{Man. orifice})}{P_b\ (OT_d + 460)} \left(\frac{(T_w + 460)^t}{CF_w} \right)$	Man.	$\Delta H_@$	$\frac{CF_w\ P_b\ (T_d\ \text{avg.} + 460)}{CF_d\ (P_b + \frac{\text{Man. orifice}}{13.6})\ (T_w + 460)}$	Man.	Y
$\frac{0.01585}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\quad + 460)\ \underline{\quad}}{\underline{\quad}} \right)^2$	.5	1.805	$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.0368)\ (\underline{\quad} + 460)}$	.5	0.997
$\frac{0.0317}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\underline{\quad} + 460)\ \underline{\quad}}{\underline{\quad}} \right)^2$	1.0	1.870	$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.0737)\ (\underline{\quad} + 460)}$	1.0	1.002
$\frac{0.0634}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\underline{\quad} + 460)\ \underline{\quad}}{\underline{\quad}} \right)^2$	2.0	2.015	$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.147)\ (\underline{\quad} + 460)}$	2.0	1.001
$\frac{0.1268}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\underline{\quad} + 460)\ \underline{\quad}}{} \right)^2$	4.0		$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.294)\ (\underline{\quad} + 460)}$	4.0	
$\frac{0.1902}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\underline{\quad} + 460)\ \underline{\quad}}{\underline{\quad}} \right)^3$	6.0		$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.431)\ (\underline{\quad} + 460)}$	6.0	
$\frac{0.2635}{\underline{\quad}\ (\underline{\quad} + 460)} \left(\frac{(\underline{\quad} + 460)\ \underline{\quad}}{\underline{\quad}} \right)^2$	8.0		$\frac{\underline{\quad}\ X\ \underline{\quad}\ (\underline{\quad} + 460)}{\underline{\quad}\ (\underline{\quad} + 0.588)\ (\underline{\quad} + 460)}$	8.0	

PITOT CALIBRATION

Pitot No. 9.3 Date 6/8/76 Engineer CAM/JK

"S" TYPE

ΔP RANGE	1		2		3		4		5		6		7	
LEG / PT.	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	.07	.07	.32	.335	.54	.56	.74	.90	1.1	1.1	1.35	1.35	1.85	1.8
2	.07	.075	.32	.33	.63	.66	.89	.95	1.2	1.5	1.6	1.6	1.8	1.8
3	.07	.08	.32	.33	.65	.66	.895	.92	1.2	1.2	1.55	1.5	1.75	1.65
4	.08	.08	.32	.32	.66	.67	.87	.91	1.2	1.5	1.5	1.5	1.7	1.6
5	.095	.09	.315	.315	.64	.66	.89	.91	1.15	1.15	1.45	1.45	1.65	1.55
6	.10	.095	.30	.315	.63	.67	.89	.895	1.1	1.1	1.40	1.4	1.65	1.6
7														
8														
AVG.	.08125		.32		.6358		0.88		1.15		1.4875		1.70	

STANDARD

ΔP / PT.	1	2	3	4	5	6	7
1	.06 .06		.38 .45		.89 .75		1.35 1.35
2	.06 .06		.47 .47		.89 .89		1.25 1.3
3	.06 .06		.47 .46		.875 .88		1.15 1.25
4	.055 .065		.46 .45		.83 .85		1.15 1.15
5	.06 .06		.46 .47		.825 .815		1.1 1.15
6	.065 .065		.475 .475		.80 .80		1.1 1.1
7							
8							
AVG.	.0608	.2213	.4675	1.125	.8412	1.065	1.20
C_p	.856	.823	.840	.826	.846	.838	.832

$$C_p = 0.99\sqrt{\frac{\Delta P_{std}}{\Delta P_{"S"}}}$$

3.0 EQUATIONS FOR SAMPLING EQUIPMENT CALIBRATION

3.1 Pitot Calibration

The Pitot tubes were calibrated by measuring the velocity head in a duct with both a Type "S" Pitot tube and a standard type Pitot tube with a known coefficient.

This was done at several different velocities. The Pitot tube coefficient can be calculated:

$$C_p \text{ test} = C_{p \text{ std}} \quad \frac{\Delta P_{std}}{\Delta P_{test}} \qquad \text{eq. 1}$$

Where:

C_p test = Pitot tube coefficient of Type "S" Pitot tube.

C_p std = Pitot tube coefficient of standard type Pitot tube.

ΔP_{std} = Velocity head measured by standard type Pitot tube.

ΔP_{test} = Velocity head measured by type "S" Pitot tube.

3.2 Dry Gas Meter and Orifice Meter

The dry gas meter and orifice were calibrated using a wet test meter. Gases were moved through the dry gas meter at Δ H's of 0.5, 1.0, 2.0, 4.0, 6.0 and 8.0. With the information obtained, γ, the ratio of accuracy of wet test meter to dry test meter, and Δ H @, the orifice pressure differential that gives 0.75 cfm of air at 70°F and 29.92 inches of mercury, were calculated. The γ has a tolerance ± 0.01 and the Δ H @ has a tolerance of ± 0.15.

$$\gamma = \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)} \qquad \text{eq. 2}$$

Where:

P_b = Barometric Pressure

V_w = Volume wet test meter

t_d = Average temperature of dry gas meter in °F

V_d = Volume dry gas meter

t_w = Temperature wet test meter in °F

$$\Delta H@ = \frac{0.0317\Delta H}{P_b\,(t_d + 460)} \left[\frac{(t_w + 460)\theta}{V_w} \right]^2 \qquad \text{Eq. 3}$$

Where:

θ = Time in minutes

ΔH = Manometer orifice pressure drop

C. Potentiometer Calibration

The Thermo Electric Potentiometers were calibrated using a known voltage source.

Calculations

The following series of equations were utilized to perform the calculations leading to the results of the program.

4.0 EQUATIONS FOR PARTICULATE CALCULATIONS

1. $M_c = 0.0474\, M_l$

2. $Q_s = 17.71 \dfrac{Q_m}{T_m + 460} (P_{bar} + .07355\ (H))$

3. $M = \dfrac{100\, M_c}{(M_c + Q_s)}$

4. $X = \dfrac{100 - M}{100}$

5. $M_w = 18(1-X) + \left[0.44\ (\%\ CO_2) + 0.28\ (\%\ CO) + 0.32(\%O_2) + 0.28\ (\%N_2)\right] X$

6. $X_a = \dfrac{100\ (\%\ O_2 - 0.5\%\ CO)}{0.264\%\ N_2 - (\%O_2 - 0.5\%\ CO)}$

7. $Cp = 0.99\ (\Delta P \text{ for Standard Pitot}/\Delta P \text{ for type "S" Pitot})^{0.5}$

8. $V_s = (85.48)(60)(C_p)\left[P_t\right]^{0.5}\left[(T_s + 460)/(P_s)(M_w)\right]^{0.5}$

9. $V_{ga} = V_s \dfrac{(A_s)}{(144)}$

10. $V_{gs} = XV_{ga} \dfrac{(530)}{(T_s + 460)} \dfrac{(P_s)}{(29.92)}$

11. $W_d = (0.0154) \dfrac{W_t}{Q_s}$

12. $W_w = (0.0154) \dfrac{W_t}{(Q_s + M_c)}$

13. $W_c = \dfrac{12\, W_d}{\%\ CO_2}$

14. $W_s = 530\, W_w \dfrac{(530)}{(T_s + 460)} \dfrac{(P_s)}{29.92}$

15. $W_p = 0.00857\, V_{gs}\, W_d$

16. $A_n = \dfrac{\pi}{144} \dfrac{(D_n)^2}{(4)}$

17. $I = \dfrac{(60)\ (1.667)\ (T_s + 460)\ (0.00267\ M_l + Q_s/17.71)}{(D)\ (V_s)\ (P_s)\ (A_n)}$

LEGEND

A_n = Area of nozzle in square feet

A_s = Stack area square inches

C_p = Pitot correction factor

D = Duration of test

D_n = Nozzle diameter in inches

g_c = $1g/(atm)(cm)(sec)^2$

H = Orifice pressure drop in inches of water

I = % Isokinetics

M = % Moisture

M_1 = Volume of liquid (in milliliters) collected in impingers and silica gel

M_c = Volume of M_1 converted to cubic feet

M_w = Molecular weight of stack gases

P_{bar} = Barometric pressure (inches of mercury)

P_s = Stack pressure absolute (inches of mercury)

P_t = Average of square roots of pressure drop across "S" pitot in $(\text{in water})^{1/2}$

Q_m = Sample volume (dry) meter conditions in cubic feet

Q_s = Sample volume (dry) standard cubic feet

T_f = Temperature after jet in ^oF

T_k = Temperature after jet in ^oK

T_m = Average meter temperature in ^oF

T_s = Average stack temperature in ^oF

V_{ga} = Stack gas flow in ACFM

LEGEND

V_{gs} = Stack gas flow in SCFM

V_s = Stack velocity feet per minute

W_c = Particulate concentration in grains per SCF (dry) at 12% CO_2

W_d = Particulate concentration in grains per SCF (dry)

W_p = Pounds per hour particulates

W_s = Particulate concentration in grains per cu. ft. (Stk. conditions)

W_t = Total weight of particulates collected in test in milligrams

W_w = Particulate concentration in grains per SCF (wet)

X = Dry sample fraction

X_a = % excess air

Equations for Sulfur Oxides Emission Calculations

1. $$\text{PPM } SO_3 = \frac{40\, T_{so_3}\, N_{so_3}\, (836)}{80\, Q_s}$$

2. $$\text{PPM } SO_2 = \frac{32\, T_{so_2}\, N_{so_2}\, (836)}{64\, Q_s}$$

3. $\text{Lbs. } SO_3/\text{hr.} = 60(V_{gs})\ (\text{PPM } SO_3)\ (2.110 \times 10^{-7})$

4. $\text{Lbs. } SO_2/\text{hr.} = 60(V_{gs})\ (\text{PPM } SO_2)\ (7.05 \times 10^{-5})$

LEGEND

N_{so_2} = Normality of titrant for SO_2

N_{so_3} = Normality of titrant for SO_3

Q_s = Sample volume (dry) standard cubic feet

T_{so_2} = Milliliters titre for SO_2

T_{so_3} = Milliliters titre for SO_3

V_{gs} = Stack gas flow in SCFM

Testing Parameters

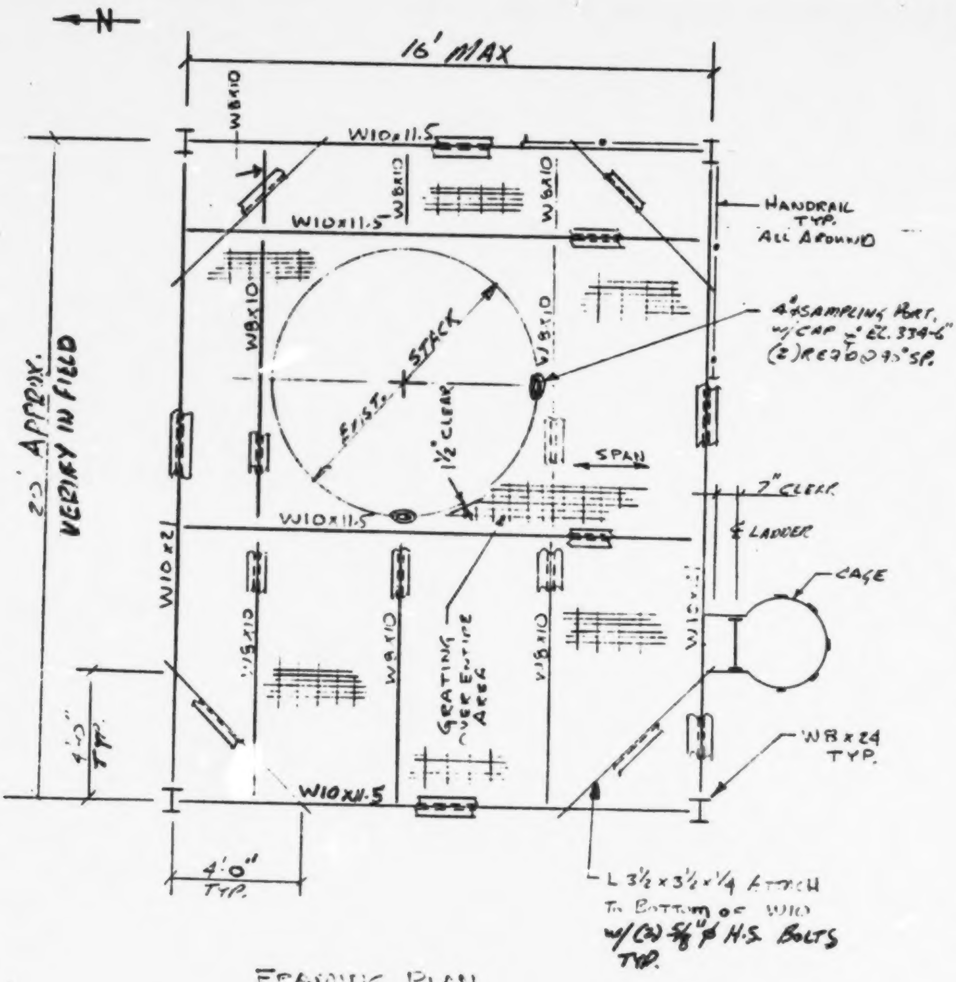
The complete results of the computer analysis of the input data generated from the particulate and sulfur oxide moisture content sampling program are presented on the following pages.

B·E·E
PLYMOUTH MEETING PENNSYLVANIA 19462

COMPUTATION SHEET

Sheet Number 1 of 1
Date 6-7-76
J. O. Number 00- 4777 -01
Computed by RED
Checked by

Name of Client Dominion Foundries & Steel
Project Cast House Emission Control Test Platform
Description Plan View



N
16' MAX
W8x10
W10x11.5
W8x10
W8x10
W10x11.5
HANDRAIL TYP. ALL AROUND
W8x10
EXIST. STACK
W8x10
4" SAMPLING PORT. w/CAP ⊕ EL. 334-6" (2) REQ'D @ 90° SP.
1½" CLEAR
SPAN
7" CLEAR
℄ LADDER
W10x11.5
22' APPROX. VERIFY IN FIELD
W10x21
W8x10
W8x10
GRATING OVER ENTIRE AREA
W8x10
W10x21
CAGE
4'-0" TYP.
W10x11.5
W8x24 TYP.
4'-0" TYP.
L 3½ x 3½ x ¼ ATTACH TO BOTTOM OF W10 w/(3) 5/8"ø H.S. BOLTS TYP.

FRAMING PLAN

¼" SCALE
T.O. GRATING EL. 333'-3"

NOTE: ALL CONSTRUCTION TO BE IN ACCORDANCE WITH DOFASCO'S STANDARDS.

BEE 17 1/71

```
               PARAMETERS  (SI UNITS)                       1-HIGH            2-HIGH           3-HIGH

AREA OF BREECHING   (SQ METER)                            3.5753E+00        3.5753E+00        3.5753E+00
SAMPLE VOLUME(DRY)  (NORM CU METER)                       6.1867E-01        4.8988E-01        8.0803E-01
MOISTURE            (%)                                    .7322            1.4846            2.8875
MOLECULAR WEIGHT    STACK GASES                          28.79636          28.71454          28.56195
GAS TEMPERATURE     ( C)                                 61.11             60.00             53.33
GAS VELOCITY        (M/S)                                 4.3641E+01        4.5568E+01        4.5663E+01
GAS VOLUME          (NM3/S)(DRY)                          1.3705E+02        1.4216E+02        1.4329E+02
GAS VOLUME          (CU M/S)                              1.5603E+02        1.6292E+02        1.6326E+02

PARTICULATE CONC :
   KG/N CU METER    (DRY BASIS)                           1.2868E-03        4.2207E-04        2.2897E-04
   KG/N CU METER    (WET BASIS)                           1.2774E-03        4.1581E-04        2.2236E-04
   KG/N CU METER    @ 12% CO2                             5.1474E-02        1.6883E-02        9.1587E-03
   KG/CU METER      (STK COND)                            1.1303E-03        3.6828E-04        2.0096E-04
   KG/S                                                   1.7633E-01        5.9990E-02        3.2803E-02

GASEOUS CONC :
   SULFUR TRIOXIDE (KG/CU M)                              6.3410E-07        7.6812E-07        1.6101E-06
   SULFUR TRIOXIDE (KG/S)                                 8.6901E-05        1.0919E-04        2.3071E-04
   SULFUR DIOXIDE  (KG/CU M)                              1.0934E-04        1.3809E-04        5.3911E-06
   SULFUR DIOXIDE  (KG/S)                                 1.4961E-02        1.9599E-02        7.7123E-04

ORSAT ANALYSIS :
   CARBON DIOXIDE  (VOL %)                                   .30               .30               .30
   CARBON MONOXIDE (VOL %)                                   .00               .00               .00
   OXYGEN          (VOL %)                                 20.70             20.70             20.70
   NITROGEN        (VOL %)                                 79.00             79.00             79.00
EXCESS AIR          (%)                                 13269.38          13269.38          13269.38
ISOKINETIC          (%)                                   101.95            100.88            101.30
```

```
          PARAMETERS (SI UNITS)                          4-LOW         5-LOW         6-MED

AREA OF BREECHING   (SQ METER)                       3.5753E+00    3.5753E+00    3.5753E+00
SAMPLE VOLUME(DRY)  (NORM CU METER)                  3.6487E-01    4.8757E-01    5.2560E-01
MOISTURE            (%)                              8.7294        9.6953        5.1588
MOLECULAR WEIGHT    STACK GASES                     27.92659      27.82154      28.31493
GAS TEMPERATURE     ( C)                            65.56         70.56         70.56
GAS VELOCITY        (M/S)                            3.0447E+01    3.3287E+01    4.8694E+01
GAS VOLUME          (NM3/S)(DRY)                     8.6498E+01    9.2576E+01    1.4232E+02
GAS VOLUME          (CU M/S)                         1.0886E+02    1.1901E+02    1.7410E+02

PARTICULATE CONC :
   KG/N CU METER    (DRY BASIS)                      3.8207E-04    5.3132E-04    4.7048E-04
   KG/N CU METER    (WET BASIS)                      3.4872E-04    4.7981E-04    4.4621E-04
   KG/N CU METER    @ 12% CO2                        1.5283E-02    2.1253E-02    1.8819E-02
   KG/CU METER      (STK COND)                       3.0359E-04    4.1329E-04    3.8460E-04
   KG/S                                              3.3043E-02    4.9179E-02    6.6947E-02

GASEOUS CONC :
   SULFUR TRIOXIDE (KG/CU M)                         5.7993E-05    2.8916E-05    3.9528E-06
   SULFUR TRIOXIDE (KG/S)                            5.0162E-03    2.6769E-03    5.6256E-04
   SULFUR DIOXIDE  (KG/CU M)                         1.5362E-04    1.6082E-04    1.2615E-04
   SULFUR DIOXIDE  (KG/S)                            1.3266E-02    1.4864E-02    1.7924E-02

ORSAT ANALYSIS :
   CARBON DIOXIDE   (VOL %)                             .30           .30           .30
   CARBON MONOXIDE  (VOL %)                             .00           .00           .00
   OXYGEN           (VOL %)                           20.70         20.70         20.70
   NITROGEN         (VOL %)                           79.00         79.00         79.00
EXCESS AIR          (%)                            13269.38      13269.38      13269.38
ISOKINETIC          (%)                              111.12        115.61         97.29
```

PARAMETERS (SI UNITS)		7-MED	8-MED	9-MED
AREA OF BREECHING	(SQ METER)	3.5753E+00	3.5753E+00	3.5753E+00
SAMPLE VOLUME(DRY)	(NORM CU METER)	6.2408E-01	2.8504E-01	1.5140E-01
MOISTURE	(%)	1.8989	8.8033	11.7376
MOLECULAR WEIGHT	STACK GASES	28.66948	27.91855	27.59942
GAS TEMPERATURE	(C)	62.22	70.00	57.22
GAS VELOCITY	(M/S)	4.5485E+01	4.6007E+01	4.2270E+01
GAS VOLUME	(NM3/S)(DRY)	1.4093E+02	1.2994E+02	1.2001E+02
GAS VOLUME	(CU M/S)	1.6262E+02	1.6449E+02	1.5113E+02
PARTICULATE CONC :				
KG/N CU METER	(DRY BASIS)	2.9390E-04	1.2253E-04	2.8145E-04
KG/N CU METER	(WET BASIS)	2.8832E-04	1.1174E-04	2.4842E-04
KG/N CU METER	@ 12% CO2	1.1756E-02	4.9012E-03	1.1258E-02
KG/CU METER	(STK COND)	2.5468E-04	9.6793E-05	2.2350E-04
KG/S		4.1411E-02	1.5919E-02	3.3771E-02
GASEOUS CONC :				
SULFUR TRIOXIDE	(KG/CU M)	2.5657E-06	5.1540E-06	3.9661E-06
SULFUR TRIOXIDE	(KG/S)	3.6157E-04	6.6969E-04	4.7597E-04
SULFUR DIOXIDE	(KG/CU M)	8.6738E-05	1.2799E-04	8.5050E-06
SULFUR DIOXIDE	(KG/S)	1.2204E-02	1.6604E-02	1.0190E-03
ORSAT ANALYSIS :				
CARBON DIOXIDE	(VOL %)	.30	.30	.30
CARBON MONOXIDE	(VOL %)	.00	.00	.00
OXYGEN	(VOL %)	20.70	20.70	20.70
NITROGEN	(VOL %)	79.00	79.00	79.00
EXCESS AIR	(%)	13269.38	13269.38	13269.38
ISOKINETIC	(%)	106.07	119.56	110.76

```
            PARAMETERS (ENGLISH UNITS)            1-HIGH       2-HIGH       3-HIGH

AREA OF BREECHING   (SQ IN)                     5541.77      5541.77      5541.77
SAMPLE VOLUME(DRY)  (STD CU FT)                   21.85        17.30        28.54
MOISTURE            (%)                             .7322       1.4846       2.8875
MOLECULAR WEIGHT    STACK GASES                   28.80        28.71        28.56
GAS TEMPERATURE     ( F)                         142          140          128
GAS VELOCITY        (FPM)                       8591         8970         8989
GAS VOLUME          (SCFM)(DRY)               290385       301211       303614
GAS VOLUME          (ACFM)                    330609       345210       345930

PARTICULATE CONC :
   GRAINS/STD CU.   FOOT (DRY BASIS)                .5623        .1844        .1001
   GRAINS/STD CU.   FOOT (WET BASIS)                .5582        .1817        .0972
   GRAINS/STD CU.   FOOT   12% CO2                22.4938       7.3778       4.0023
   GRAINS/CU.       FOOT (STK COND)                 .4939        .1609        .0878
   POUNDS/HOUR                                  1399.4504     476.1228     260.3473

GASEOUS CONC :
   SULFUR TRIOXIDE (PPM)                            .1904        .2306        .4835
   SULFUR TRIOXIDE (#/HR)                           .6897        .8666       1.8310
   SULFUR DIOXIDE  (PPM)                          41.0329      51.8205       2.0231
   SULFUR DIOXIDE  (#/HR)                        118.7397     155.5471       6.1210

ORSAT ANALYSIS :
   CARBON DIOXIDE  (VOL %)                         .30          .30          .30
   CARBON MONOXIDE (VOL %)                         .00          .00          .00
   OXYGEN          (VOL %)                       20.70        20.70        20.70
   NITROGEN        (VOL %)                       79.00        79.00        79.00
EXCESS AIR         (%)                        13269.38     13269.38     13269.38
ISOKINETIC         (%)                          101.95       100.88       101.30
```

```
              PARAMETERS (ENGLISH UNITS)              4-LOW          5-LOW          6-MED

 AREA OF BREECHING   (SQ IN)                       5541.77        5541.77        5541.77
 SAMPLE VOLUME(DRY)  (STD CU FT)                     12.89          17.22          18.56
 MOISTURE            (%)                              8.7294         9.6953         5.1588
 MOLECULAR WEIGHT    STACK GASES                     27.93          27.82          28.31
 GAS TEMPERATURE     ( F)                           150            159            159
 GAS VELOCITY        (FPM)                         5993           6553           9585
 GAS VOLUME          (SCFM)(DRY)                 183278         196156         301559
 GAS VOLUME          (ACFM)                      230655         252175         368889

 PARTICULATE CONC :
    GRAINS/STD CU.   FOOT (DRY BASIS)                  .1670          .2322          .2056
    GRAINS/STD CU.   FOOT (WET BASIS)                  .1524          .2097          .1950
    GRAINS/STD CU.   FOOT   12% CO2                   6.6785         9.2874         8.2238
    GRAINS/CU.       FOOT (STK COND)                   .1327          .1806          .1681
    POUNDS/HOUR                                     262.2470       390.3177       531.3339

 GASEOUS CONC :
    SULFUR TRIOXIDE (PPM)                            17.4133         8.6826         1.1869
    SULFUR TRIOXIDE (#/HR)                           39.8119        21.2458         4.4648
    SULFUR DIOXIDE  (PPM)                            57.6490        60.3493        47.3385
    SULFUR DIOXIDE  (#/HR)                          105.2910       117.9679       142.2575

 ORSAT ANALYSIS :
    CARBON DIOXIDE   (VOL %)                          .30            .30            .30
    CARBON MONOXIDE  (VOL %)                          .00            .00            .00
    OXYGEN           (VOL %)                        20.70          20.70          20.70
    NITROGEN         (VOL %)                        79.00          79.00          79.00
 EXCESS AIR          (%)                         13269.38       13269.38       13269.38
 ISOKINETIC          (%)                           111.12         115.61          97.29
```

```
               PARAMETERS (ENGLISH UNITS)             7-MED          8-MED          9-MED

AREA OF BREECHING    (SQ IN)                        5541.77        5541.77        5541.77
SAMPLE VOLUME(DRY)   (STD CU FT)                      22.04          10.07           5.35
MOISTURE             (%)                               1.8989         8.8033        11.7376
MOLECULAR WEIGHT     STACK GASES                      28.67          27.92          27.60
GAS TEMPERATURE      ( F)                            144            158            135
GAS VELOCITY         (FPM)                          8954           9056           8321
GAS VOLUME           (SCFM)(DRY)                  298604         275323         254286
GAS VOLUME           (ACFM)                       344580         348532         320224

PARTICULATE CONC :
   GRAINS/STD CU.    FOOT (DRY BASIS)                  .1284          .0535          .1230
   GRAINS/STD CU.    FOOT (WET BASIS)                  .1260          .0488          .1086
   GRAINS/STD CU.    FOOT   12% CO2                   5.1373         2.1418         4.9197
   GRAINS/CU.        FOOT (STK COND)                   .1113          .0423          .0977
   POUNDS/HOUR                                      328.6620       126.3412       268.0303

GASEOUS CONC :
   SULFUR TRIOXIDE (PPM)                               .7704         1.5476         1.1909
   SULFUR TRIOXIDE (#/HR)                             2.8697         5.3151         3.7776
   SULFUR DIOXIDE  (PPM)                             32.5495        48.0296         3.1916
   SULFUR DIOXIDE  (#/HR)                            96.8567       131.7770         8.0876

ORSAT ANALYSIS :
   CARBON DIOXIDE   (VOL %)                           .30            .30            .30
   CARBON MONOXIDE  (VOL %)                           .00            .00            .00
   OXYGEN           (VOL %)                         20.70          20.70          20.70
   NITROGEN         (VOL %)                         79.00          79.00          79.00
EXCESS AIR          (%)                          13269.38       13269.38       13269.38
ISOKINETIC          (%)                            106.07         119.56         110.76
```

Analytical Methods

All filters and Andersen plates in the sampling program were analyzed on-site by B.E.E. personnel. All other samples were returned to B.E.E. LABORATORIES, INC. of PLYMOUTH MEETING PENNSYLVANIA for analysis. The following discussions describe the analytical methods employed.

Particulate Samples--

All glass fiber filters used in particulate sampling had been tare weighed following a twenty-four (24) hour drying period at 105°C and desiccation prior to their use in the field. Upon their return to the laboratory, they were dried for twenty-four (24) hours at 105°C, desiccated and reweighed to constant weight. The weight difference was the amount of sample collected on the filter.

Moisture Content--

The total volume of the impinger solutions minus the original volume of reagents in the impingers plus the volume of moisture and/or vapors collected by the silica gel equalled the total moisture gain of the sampling train. This volume was used as the basis for percent moisture by volume calculations. The laboratory results of the moisture analyses appear concurrently with the results of the particulate testing program on page C-49

Particulate Size Distribution - Andersen--

All sample collection plates were dried in a desiccator for a minimum of twelve hours and then tare weighted prior to their use in the field. Upon their return to the laboratory, they were desiccated and reweighed. The weight difference was the amount of sample collected on a particular plate during a sample run. Acetone washings and filters were treated as per the procedure outlined in "Particulate Samples' above.

Sulfur Dioxide Samples--

The analysis of the sulfur dioxide samples was conducted utilizing the following method as specified in the Federal Register.

An aliquot was taken and isopropyl alcohol was added. The sample was then titrated to its thorin endpoint with 0.01N Ba $(ClO_4)_2$ (barium perchlorate).

3.2 Andersen Classification Figures 1,2&3

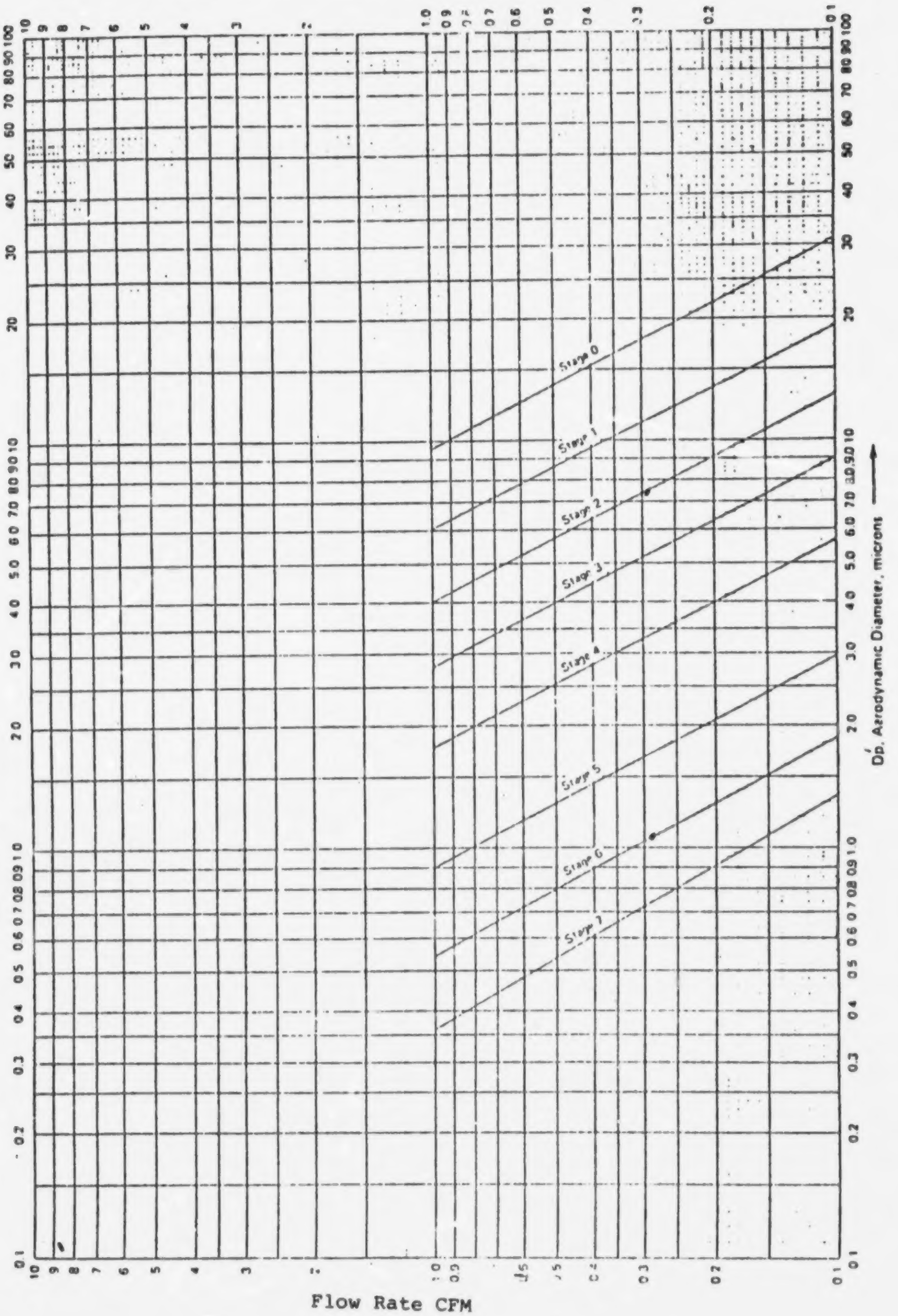


Figure 1. Aerodynamic Diameter Versus Flow rate through Andersen Stack Sampler

Figure 2 Density Correction Factor for Physical Size of Particles Captured in Andersen Stack Sampler

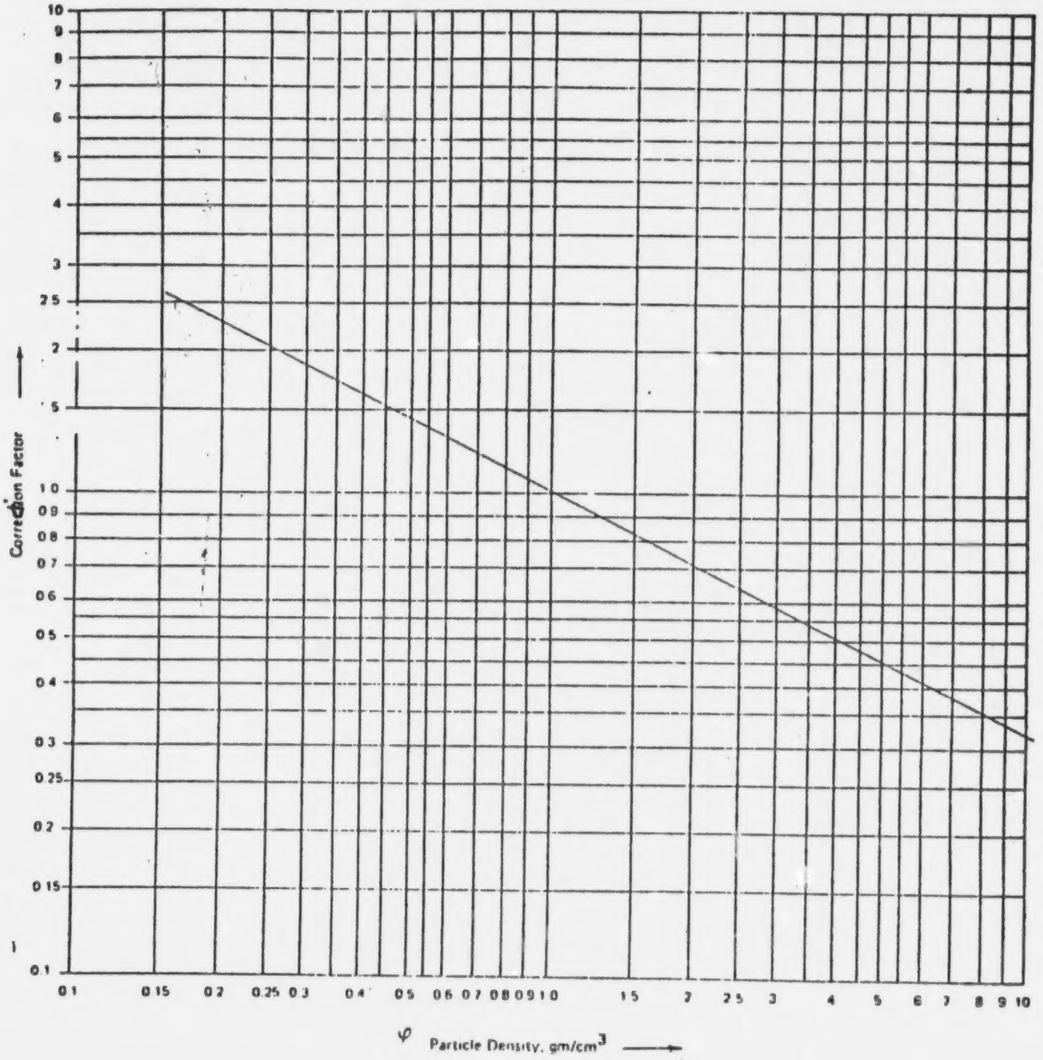
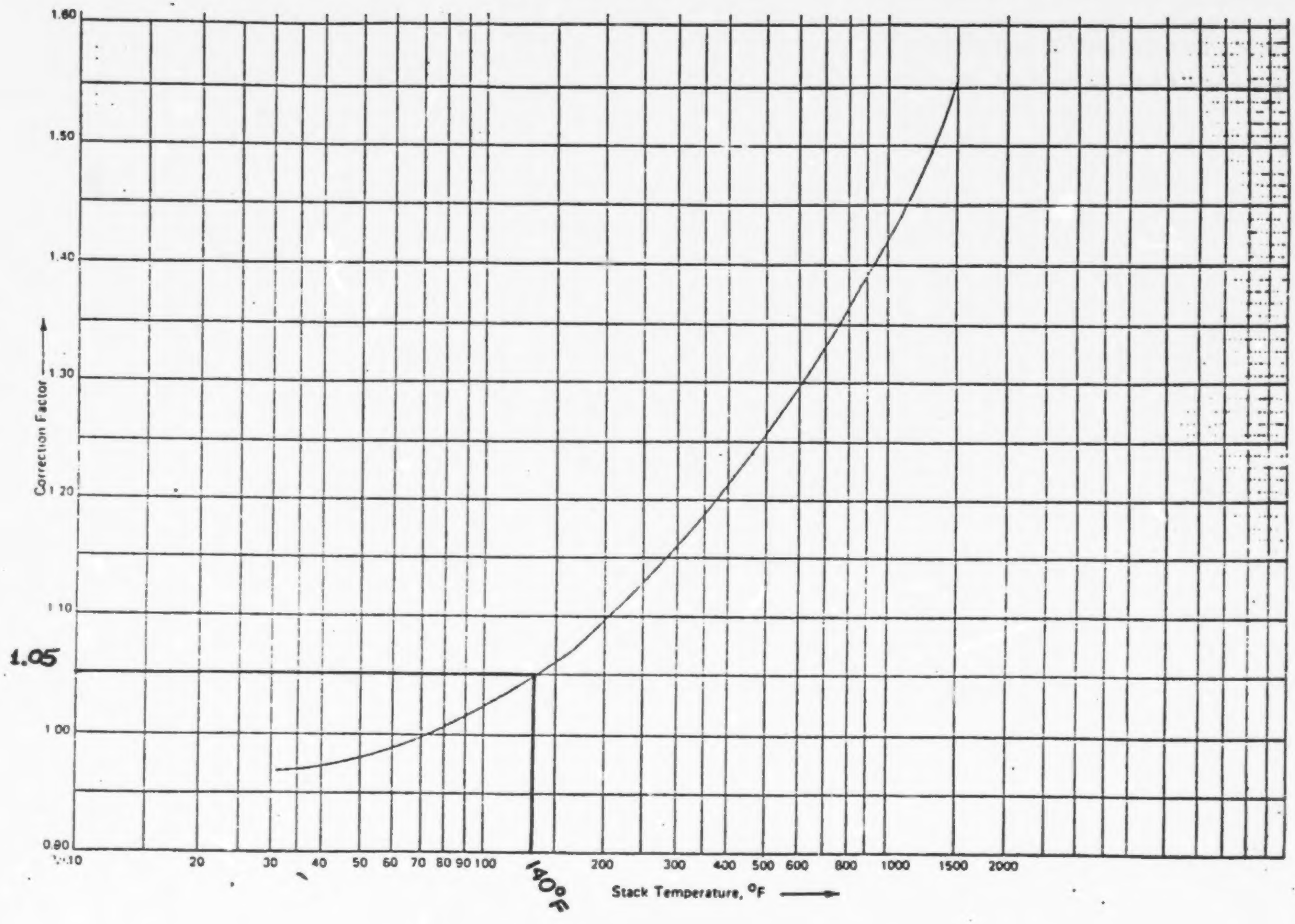


Figure 3. Temperature Correction Factor for Aerodynamic Size of Particles Captured in Andersen Stack Sampler



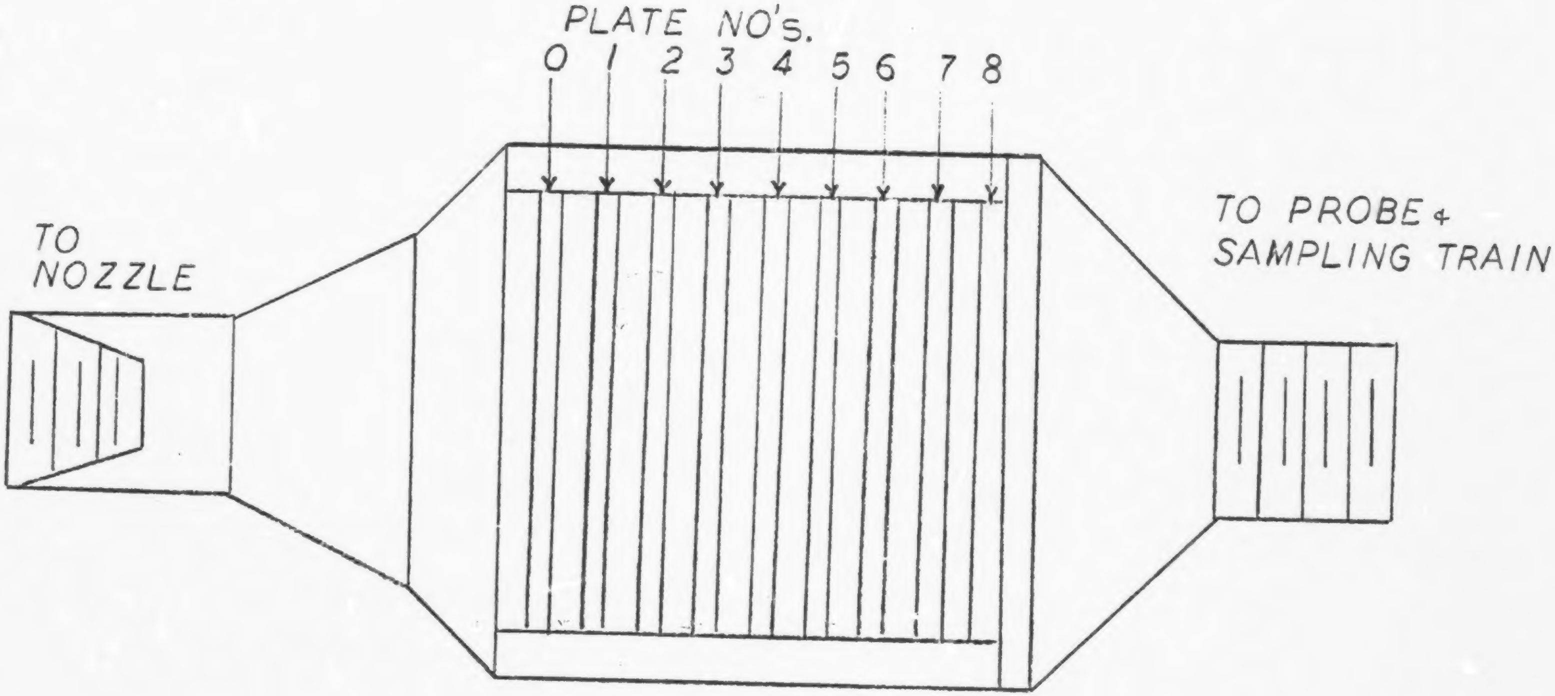
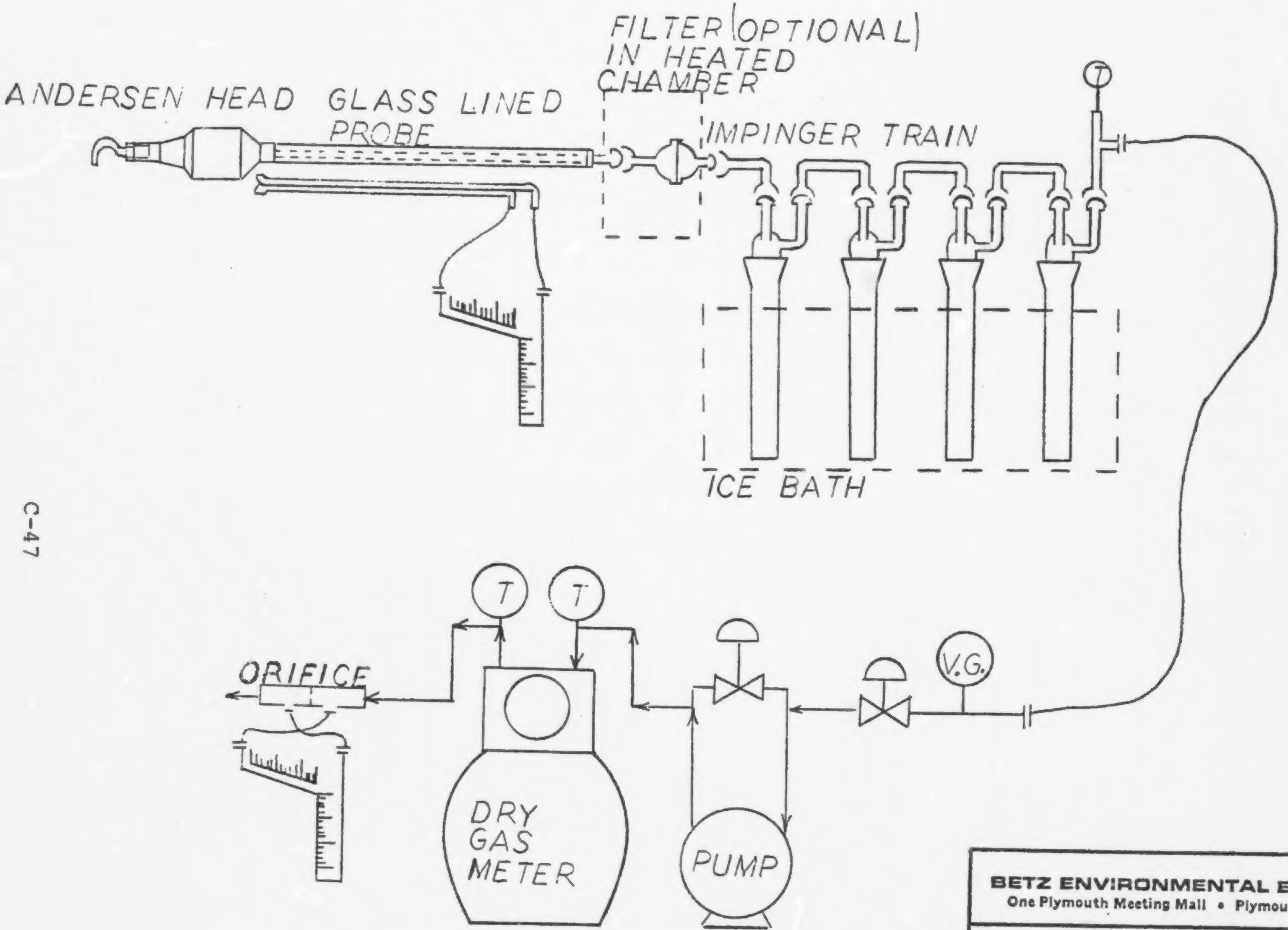


PLATE NO'S.
0
1
2
3
4
5
6
7
8
TO NOZZLE
TO PROBE + SAMPLING TRAIN

BETZ ENVIRONMENTAL ENGINEERS, Inc.
One Plymouth Meeting Mall • Plymouth Meeting, Pa. 19462

FOR
TITLE ANDERSEN IMPACTOR DIAGRAM
DRAWN BY FJK
DATE 6/18/75
APPROVED BY
DRAW NO
SCALE NONE


ANDERSEN HEAD
GLASS LINED PROBE
FILTER (OPTIONAL) IN HEATED CHAMBER
IMPINGER TRAIN
T
ICE BATH
V.G.
T
T
ORIFICE
DRY GAS METER
PUMP

BETZ ENVIRONMENTAL ENGINEERS, Inc.
One Plymouth Meeting Mall • Plymouth Meeting, Pa. 19462

FOR

TITLE ANDERSEN HEAD SAMPLING TRAIN

DRAWN BY FJK

DATE 6/18/75

APPROVED BY

DRAW NO

SCALE NONE

BETZ ENVIRONMENTAL ENGINEERS, Inc.

NOMOGRAPH DATA

PLANT DOFASCO (EPA)

DATE 24 August 1976

SAMPLING LOCATION Bypass Stack

Andersen System

CALIBRATED PRESSURE DIFFERENTIAL ACROSS ORIFICE, in. H_2O Box #5	$\Delta H_@$	1.99
AVERAGE METER TEMPERATURE (AMBIENT + 20 °F), °F	$T_{m\,avg.}$	95
PERCENT MOISTURE IN GAS STREAM BY VOLUME	B_{wo}	2.5
BAROMETRIC PRESSURE AT METER, in. Hg	P_m	-
STATIC PRESSURE IN STACK, in. Hg ($P_m \pm 0.073$ x STACK GAUGE PRESSURE in in. H_2O)	C_p	.83
RATIO OF STATIC PRESSURE TO METER PRESSURE	P_s/P_m	-
AVERAGE STACK TEMPERATURE, °F	$T_{s\,avg.}$	110
AVERAGE VELOCITY HEAD, in. H_2O	$\Delta p_{avg.}$	4.8
MAXIMUM VELOCITY HEAD, in. H_2O	$\Delta p_{max.}$	-
C FACTOR	1.15	
CALCULATED NOZZLE DIAMETER, in.	0.135	
ACTUAL NOZZLE DIAMETER, in. Set 1	0.120	
REFERENCE Δp, in. H_2O	7.8	

EPA (Dur) 234
4/72

LABORATORY RESULTS OF THE PARTICULATE/MOISTURE TESTS

Run No.	Filter Gain (mg)	Nozzle, Probe and Filter Holder Gain (mg)	Nozzle, Probe and Filter Holder Gain (%)	Total Particulate Gain (mg)	Impinger Gain (mls)	Silica Gel Gain (mls)	Total Moisture Pick-Up (mls)
1	224.3	573.5	71.9	797.8	-7	10.4	3.4
2	56.2	151.0	72.9	207.2	-2	7.5	5.5
3	58.4	127.0	68.5	185.4	6	11.9	17.9
4	48.5	91.2	65.3	139.7	18	8.0	26.0
5	111.1	148.5	57.2	259.6	29	10.0	39.0
6	122.5	125.3	50.6	247.8	13	8.3	21.3
7	35.6	148.2	80.6	183.8	0	9.0	9.0
8	13.5	21.5	61.4	35.0	16	4.5	20.5
9	26.5	16.2	37.9	42.7	10	5.0	15.0

PERSONNEL SAMPLER LABORATORY RESULTS

Run No.	Filter Gain	Cyclone Gain	Total
2 + 3H	1.8 mg	1.092 mg	2.892 mg
4 + 5L	0.5 mg	19.913 mg	20.413 mg

LABORATORY RESULTS OF SO_3/SO_2 ANALYSES

Run-ID	Sol'n Vol.	Aliq. Vol.	Factor	Titrant (mls)	Total (mls)	(N)$Ba(ClO_4)_2$
1 SO_3	123	50	2.46	0.4	0.98	0.01
1 SO_2	320	5	64	3.3	211.2	0.01
2 SO_3	118	25	4.72	0.2	0.94	0.01
2 SO_2	330	5	66	3.2	211.2	0.01
3 SO_3	116	25	4.64	0.7	3.25	0.01
3 SO_2	340	5	68	2.2	13.6	0.01
4 SO_3	118	25	4.72	11.2	52.86	0.01
4 SO_2	350	1	350	0.5	175.0	0.01
5 SO_3	119	25	4.76	7.4	35.22	0.01
5 SO_2	360	5	72	3.4	244.8	0.01
6 SO_3	118	25	4.72	1.1	5.19	0.01
6 SO_2	345	5	69	3.0	207	0.01
7 SO_3	125	25	5	0.8	4.0	0.01
7 SO_2	325	5	65	2.6	169	0.01
8 SO_3	131	25	5.24	0.7	3.67	0.01
8 SO_2	335	5	67	1.7	113.9	0.01
9 SO_3	125	25	5	0.3	1.5	0.01
9 SO_2	335	25	13.4	0.3	4.02	0.01

DOFASCO, Hamilton, Ontario, Canada

Blast Furnace No. 1 Daily Cast Reports

Reproduced from best available copy.

DAILY CAST REPORT – BLAST FURNACE

#1 FURNACE

DATE: Aug 24/76

CAST NO.	TIME	TONN.		SIL.	SUL.	MN.
3474	8:50 am 2750	147 119 266	4 1	79 92	~~059~~ 020 ~~048~~ 022	1.39 1.39
3475	12:10 pm 2740	166 117 283	18 15	.65 .64	~~054~~ 016 ~~058~~ 019	1.37 1.34
3476	8:45 pm 2700	166 57 223	18 15	85 83	~~044~~ 010 ~~040~~	139 138
3477	12:10 am 2750	170 88 258	11 20	89 80	~~048~~ 018 ~~048~~	141 136
3478 1313	3:45 am 2830	172 111 283	23 22	1.07 .80	~~039~~ 016 ~~037~~ 028	1.44 1.35
3479	6:45 am 2800	181 21 202	3 17	70	~~033~~ 022	1.52
		1515				

DAILY CAST REPORT – BLAST FURNACE

#1 FURNACE

DATE: Aug 25/76

CAST NO.	TIME	TONN.		SIL.	SUL.	MN.
3480 30 2H	9:50 am 2600	141 119 260	5 8	.65 .68	~~042~~ 014 ~~033~~ 023	1.39 1.42
3481 3H 44	4:15 pm 2720	150 144 294	12 20	.74 .61	~~038~~ ~~040~~ 012	1.41 1.39
3482 36 2	7:25 pm 2760	162 100 262	16 17	89 80	~~034~~ 018 ~~036~~ 024	153 1.45
3483	10:35 pm 2780	161 29 190	21 1	78	~~036~~ 014	1.52
3484	1:05 am 2840	171 57 228	6 4	97 69	~~044~~ 020 044	1.51 1.44
3485	4:30 am 2840	153 164 317	8 11	79 84	~~033~~ 000 ~~034~~ 008	145 148
3486	7:55 am 2840	168 120 288	16 18	.80 66	~~028~~ 016 ~~028~~ 012	1.51 1.46
		1839				

DAILY CAST REPORT – BLAST FURNACE

#1 FURNACE

DATE: Aug 26/76

CAST NO.	TIME	TONN.		SIL.	SUL.	MN.
3487 36 56	11:53 am 2700	177 126 303	12 6	.51 61	~~036~~ 019 ~~036~~ 018	1.44 1.48
3488 30 6M	2:35 pm 2770	178 157 335	18 4	.50 47	~~048~~ 022 ~~052~~ 019	1.35 1.43
3489 33 7M	7:00 pm 2850	176 183 359	12 6	105 80	~~040~~ 012 ~~044~~ 014	145 130
3490 1265	2:10 am 2750	172 96 268	15 6	79 70	~~054~~ 018 ~~048~~ 028	1.19 1.21
3491 1561	6:00 am 2750	150 146 296	2 13	64 64	~~048~~ 04 ~~044~~ 014	129 132
	1861					

DAILY CAST REPORT – BLAST FURNACE

#1 FURNACE

DATE: AUG 27/76

CAST NO.	TIME	TONN.		SIL.	SUL.	MN.
3492 15 9M	9:15 AM 2810	176 71 247	14 22	77 67	~~044~~ 022 ~~050~~	139 135
3493 12 9M	12:35 PM 2780	141 144 283	5 9	80 78	~~072~~ 010 ~~080~~ 010	129 1.34
3494	4:25 PM 2730	171 168 339	15 17	64 74	~~056~~ 014 ~~056~~ 016	135 137
3495 1134	7:40 pm 2800	163 122 285	10 11	.63 .58	~~068~~ 014 ~~058~~ 018	1.35 1.34
3496	5:25 am 2720	163 103 266	18 21	.52 .54	~~070~~ 014 ~~068~~ 028	1.19 1.27
	1420					

DOFASCO, Hamilton, Ontario, Canada
Blast Furnace No. 1 Operation Report
August 24, 1976

```
   DAILY BLAST FURNACE OPERATI
'==================================
'          "   NO.  1 FURNACE     '
' BURDEN " %   NT/DAY  NT/MON     '
'==================================
'SHERMAN "28.7  551.7  18193.4'
'WABUSH  "23.5  452.2  16291.6'
'ADAMS   "37.7  723.5  22604.3'
'C.LAKE  "               221.2'
'ITABIRA "10.1  193.4   6492.1
'WILLIAMS"                    '
'TOTAL   "     1920.3  63802.9'
'==================================
'MILLSCLE"                    '
'BR-T.ORE"3.33 1920.8  63802.9'
'==================================
'FE SCRAP"       79.2   2525.3'
'BR-T.MET"3.47 2000.0  66328.2'
'==================================
'COKE PRD"      576.4  18442.7'
'   STOCK"                    '
'     NUT"                    '
'TOT COKE"      576.4  18442.8'
'==================================
'M.S.SLAG"      198.0   6129.0'
'LIMESTON"       35.6   1155.5'
'DOLOMITE"       68.9   2155.5'
'TOT CHGE"     2878.9  94211.2'
'==================================
'         "   8-4   4-12   12-8 '
'CHARGES  "   23     27     38  '
'TOT-AVG  "   88           113  '
'FILL-SEQ"OOSCCC/OOSCC          '
'=============================================
'              " TOTAL  TOTAL/AVG "  # 1 FURNACE  '
' PRODUCTION   "  DAY     MONTH   "  DAY    MONTH '
'=================================================:
'GROSS PROD   " 7682.2  201936.7  "1509.3  45887.0'
'GROSS-AVG    "           8077.5  "         1835.5"
'GROSS TO PCM"            8341.1  "          577.3"
'NET FROM PCM"            7983.6  "          550.5"
'M.S. GROSS   " 7682.2  192037.6  "1509.3  44758.2'
'COLD IRON    "           1577.8  "          571.3"
"INVENTORY    "                   "               '
"REC COLD IRN"             771.8  "               '
"M.S. NET     " 7682.2  191265.6  "               '
"DFS          "           1705.4  "          550.5"
'=================================================
"   TONS ON HEARTH                "      923536   '
"            STACK                "      923536   '
"-------------------------------------------------
```

Tues
24

```
              "   NO 1 FURNACE          "
              " CAST 3474 TO 3479       "
              "TEMP  SIL% SUL% MN%      "
"=========================================
              "2750  .82 .046 1.39"
Cast No. 3475"2740   .65 .054 1.26"
              "2700  .84 .045 1.39"
              "2750  .86 .046 1.39"
              "2830  .96 .031 1.40"
              "2800  .70 .032 1.52"
              "                   "
"=========================================
       DAY AVG "2761  .80 .042 1.40"
       MTD AVG "2776  .81 .047 1.39"
"=========================================
 PARAMETERS         "    DAY        MONTH '
"=========================================
COKE #/NTHM         "    764          804 "
OIL #/NTHM          "    177          137 "
TAR LB/NTHM         "                  80 "
CARB #/NTHM         "    832          906 "
FLUX #/NTHM         "    138          144 "
BOF SLAG #/NTHM"         262          267 "
O2 NT               "                     "
DRY DUST #/NTHM"          15           21 "
BLAST TEMP F        "   1706         1800 "
TOP TEMP F          "    391          401 "
BLAST PRESS PSI"        23.6         26.7"
TOP PRESS PSI       "    5.0          5.1"
MOISTURE GR/CF      "    7.2          9.5"
O2 IN BLAST %       "   21.0         21.0"
ORDERED WIND CF"       61100        65828 "
AVG WIND CFM        "  44800        59476 "
CF 21% O2 WD/#C"        51.4         51.5"
TURBO BLOWER #      "      2              "
TOT OPER DELAYS"         375         3750 "
     CAST DELAYS"         21          469 "
OIL USED GALS       "  26780       632340 "
TAR USED GALS       "              302750 "
"-----------------------------------------
```

Slag
Analysis (%)

```
'          " NO 1 FURNACE  "
'          " DAY     MONTH "
'=========="===============" 
'K2O      "    .51     .60 "
'S        "   2.02    1.84 "
'FEO      "    .51     .52 "
'CAO      "  39.71   39.19 "
'MN       "    .64     .76 "
'SIO2     "  36.58   36.61 "
'MGO      "  10.48   10.19 "
'AL2O3    "   8.59    8.72 "
'---------"----------------"
```

DOFASCO, Hamilton, Ontario, Canada
Blast Furnace No. 1 - Operating Report
August 25, 1976

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```
    DAILY BLAST FURNACE OPERATIN
"========== ============= ==========
"          "     NO.  1 FURNACE     "
" BURDEN " %     NT/DAY   NT/MON   "
"========== ============= ==========
'SHERMAN  "28.6   697.6   18891.0"
'WABUSH   "24.2   588.6   16880.2"
'ADAMS    "37.1   904.7   23509.0"
'C.LAKE   "                 221.2"
'ITABIRA  "10.1   245.3    6737.4"
'WILLIAMS"                       "
'TOTAL    "      2436.2   66239.1"
'========== ============= ==========
'MILLSCLE"                       "
'BR-T.ORE"3.41   2436.2   66239.1"
'========== ============= ==========
'FE SCRAP"         97.2    2622.5"
'BR-T.MET"3.55   2533.4   68861.6"
'========== ============= ==========
'COKE PRD"        714.0   19156.7"
'   STOCK"                       "
'     NUT"                       "
'TOT COKE"        714.0   19156.8"
'========== ============= ==========
'M.S.SLAG"        247.5    6376.5"
'LIMESTON"         45.2    1200.7"
'DOLOMITE"         90.2    2245.7"
'TOT CHGE"       3630.3   97841.4"
'========== ============= ==========
'         "    8-4    4-12   12-8 "
'CHARGES "     27      40      42 "
'TOT-AVG "     109            112 "
'FILL-SEQ"OOSCCC/OOSCC            "
'========== ============= ==========
```

Wed.
25

```
                    "     NO 1 FURNACE
                    " CAST 3480 TO 3486
                    "TEMP  SIL% SUL% MN%
=========================================
Cast No. 34?0-"2600   .64 .045 1.40
          3481-"2720   .68 .038 1.40
          3482-"2760   .86 .036 1.50
               "2780   .78 .036 1.52
               "2840   .90 .044 1.49
               "2840   .82 .033 1.47
               "2840   .74 .028 1.49
"========================================
         DAY AVG "2768  .77 .037 1.46
       MTD AVG   "2776  .81 .047 1.39
"========================================
 PARAMETERS          "   DAY        MONTH '
"========================================
COKE #/NTHM          "   779          803 '
OIL #/NTHM           "   196          139 '
TAR LB/NTHM          "                 77 '
CARB #/NTHM          "   862          904 '
FLUX #/NTHM          "   148          144 '
BOF SLAG #/NTHM"         270          267 '
O2 NT                "                    '
DRY DUST #/NTHM"           3           20 '
BLAST TEMP F         "  1800         1800 '
TOP TEMP F           "   420          402 '
BLAST PRESS PSI"        27.9         26.8'
TOP PRESS PSI        "   5.0          5.1'
MOISTURE GR/CF       "  10.0          9.6'
O2 IN BLAST %        "  21.0         21.0'
ORDERED WIND CF"       66600        65858 '
AVG WIND CFM         " 57500        59400 '
CF 21% O2 WD/#C"        52.4         51.6'
TURBO BLOWER #       "     2              '
TOT OPER DELAYS"         180         3930 '
    CAST DELAYS"          25          494 '
OIL USED GALS        " 36010       668350 '
TAR USED GALS        "             302750 '
"-----------------------------------------
```

```
'                "  TOTAL   TOTAL/AVG "  # 1 FURNACE   '
' PRODUCTION     "   DAY      MONTH   "  DAY     MONTH '
"========================================================
'GROSS PROD      " 9021.2   210957.7 "1832.3   47719.3'
'GROSS-AVG       "            8113.8 "          1835.4'
'GROSS TO PCM"      55.5     8396.6 "           577.3'
'NET FROM PCM"      53.3     8036.9 "           550.5'
'M.S. GROSS      " 8965.7   200983.3 "1832.3   46570.5'
'COLD IRON       "            1577.8 "           571.3'
'INVENTORY       "                   "                '
'REC COLD IRN"                 771.8 "                '
'M.S. NET        " 8965.7   200211.4 "                '
'DFS             "   53.3     1759.7 "           550.5'
'========================================================
'    TONS ON HEARTH                   "    925369      '
'              STACK                  "    925369      '
'--------------------------------------------------------
```

SLAG
ANALYSIS (%)

```
"--------------------------------
"         " NO 1 FURNACE  "
"         " DAY     MONTH "
"========="================"
"K20      "   .47     .59 "
"S        "  1.96    1.85 "
"FEO      "   .50     .52 "
"CAO      " 39.93   39.22 "
"MN       "   .67     .76 "
"SI02     " 36.49   36.61 "
"MGO      " 10.83   10.22 "
"AL203    "  8.62    8.72 "
"========="================"
```

DOFASCO, Hamilton, Ontario, Canada
Blast Furnace No. 1 Operating Report
August 26, 1976

DAILY BLAST FURNACE OPERATI

BURDEN	%	NO. 1 FURNACE NT/DAY	NT/MON
SHERMAN	30.5	739.2	19630.2
WABUSH	20.7	501.2	17381.4
ADAMS	38.8	939.6	24443.6
C.LAKE			221.2
ITABIRA	10.0	243.0	6980.4
WILLIAMS			
TOTAL		2423.0	68662.1
MILLSCLE			
BR-T.ORE	3.43	2423.0	68662.1
FE SCRAP		72.0	2694.5
BR-T.MET	3.53	2495.0	71356.6
COKE PRD		707.4	19864.1
STOCK			
NUT			
TOT COKE		707.4	19864.2
M.S.SLAG		243.0	6619.5
LIMESTON		30.5	1231.2
DOLOMITE		86.5	2332.2
TOT CHGE		3562.4	101403.8

	8-4	4-12	12-8
CHARGES	45	20	43
TOT-AVG	108		112
FILL-SEQ	00SCCC/00SCC		

PRODUCTION	TOTAL DAY	TOTAL/AVG MONTH	# 1 FURNACE DAY	# 1 FURNACE MONTH
GROSS PROD	8052.3	219010.0	1604.8	49324.1
GROSS-AVG		8111.5		1826.8
GROSS TO PCM	249.3	8645.9		577.3
NET FROM PCM	239.7	8276.6		550.5
M.S. GROSS	7303.0	203786.3	1604.8	48175.3
COLD IRON		1577.8		571.3
INVENTORY				
REC COLD IRN		771.8		
M.S. NET	7303.0	203014.2		
DFS		1759.7		550.5
TONS ON HEARTH				926974
STACK				926974

Thurs.
26

	NO 1 FURNACE CAST 3487 TO 3491 TEMP	SIL%	SUL%	MN%
Cast No. 3487-	2700	.55	.034	1.46
" " 3488-	2770	.49	.039	1.39
" " 3489-	2850	.92	.040	1.37
	2750	.76	.052	1.18
	2750	.64	.046	1.30
DAY AVG	2764	.67	.042	1.34
MTD AVG	2775	.80	.047	1.39

PARAMETERS	DAY	MONTH
COKE #/NTHM	882	805
OIL #/NTHM	76	137
TAR LB/NTHM	139	79
CARB #/NTHM	976	906
FLUX #/NTHM	146	144
BOF SLAG #/NTHM	303	268
02 NT		
DRY DUST #/NTHM	7	20
BLAST TEMP F	1800	1800
TOP TEMP F	348	400
BLAST PRESS PSI	23.3	26.6
TOP PRESS PSI	4.8	5.1
MOISTURE GR/CF	10.9	9.6
02 IN BLAST %	21.0	21.0
ORDERED WIND CF	62600	65737
AVG WIND CFM	53800	59193
CF 21% 02 WD/#C	49.5	51.5
TURBO BLOWER #	2	
TOT OPER DELAYS	240	4170
CAST DELAYS	18	512
OIL USED GALS	12280	680630
TAR USED GALS	18410	321160

Slag Analysis (%).

	NO 1 FURNACE DAY	MONTH
K20	.55	.59
S	1.83	1.85
FEO	.49	.52
CAO	39.78	39.24
MN	.72	.76
SI02	36.55	36.61
MGO	10.50	10.23
AL203	8.75	8.72

DOFASCO, Hamilton, Ontario, Canada
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August 27, 1976

	NO 1 FURNACE CAST 3492 TO 3496 TEMP	SIL%	SUL%	MN%
Cast No. 3492	2810	.74	.046	1.38
" " 3493	2780	.79	.076	1.32
	2790	.69	.055	1.36
	2800	.61	.056	1.35
	2720	.52	.061	1.22
DAY AVG	2780	.67	.059	1.32
MTD AVG	2776	.80	.047	1.39

BURDEN	%	NO. 1 FURNACE NT/DAY	NT/MOH
SHERMAN	29.8	648.6	20273.8
WABUSH	22.5	490.9	17872.3
ADAMS	37.8	823.0	25271.6
C.LAKE			221.2
ITABIRA	9.9	215.6	7196.0
WILLIAMS			
TOTAL		2178.1	70840.1
MILLSCLE			
BR-T.ORE	3.54	2178.1	70840.1
FE SCRAP			2694.5
BR-T.MET	3.54	2178.1	73534.7
COKE PRD		615.7	20479.8
STOCK			
NUT			
TOT COKE		615.7	20479.9
M.S.SLAG		208.3	6827.7
LIMESTON		36.2	1267.4
DOLOMITE		90.7	2422.9
TOT CHGE		3129.0	104532.7

	8-4	4-12	12-8
CHARGES	42	23	29
TOT-AVG	94		112
FILL-SEQ	OOSCCC/OOSCC		

Frid.
27

PARAMETERS	DAY	MONTH
COKE #/NTHM	869	807
OIL #/NTHM		134
TAR LB/NTHM	200	82
CARB #/NTHM	954	908
FLUX #/NTHM	179	45
BOF SLAG #/NTHM	294	269
02 NT		
DRY DUST #/NTHM	8	19
BLAST TEMP F	1797	1800
TOP TEMP F	365	399
BLAST PRESS PSI	28.6	26.7
TOP PRESS PSI	4.9	5.1
MOISTURE GR/CF	12.2	9.7
02 IN BLAST %	21.0	21.0
ORDERED WIND CF	65800	65739
AVG WIND CFM	47300	58768
CF 21% 02 WD/#C	50.4	51.4
TURBO BLOWER #	2	
TOT OPER DELAYS	405	4575
CAST DELAYS	10	522
OIL USED GALS		680630
TAR USED GALS	23370	344530

PRODUCTION	TOTAL DAY	TOTAL/AVG MONTH	# 1 FURNACE DAY	# 1 FURNACE MONTH
GROSS PROD	8257.4	227267.4	1417.1	50741.2
GROSS-AVG		8116.7		1812.2
GROSS TO PCM	316.4	8962.3		577.3
NET FROM PCM	303.7	8530.3		550.5
M.S. GROSS	7941.0	216727.2	1417.1	49592.4
COLD IRON		1577.8		571.3
INVENTORY				
REC COLD IRN	59.5	831.3		
M.S. NET	7881.5	215895.7		
DFS	16.1	1775.3		550.5

SLAG ANALYSIS (%)

	NO 1 FURNACE DAY	MONTH
K20	.76	.60
S	1.54	1.84
FEO	.50	.52
CAO	38.84	39.23
MN	.81	.76
SI02	37.14	36.63
MGO	10.41	10.23
AL203	8.73	8.72

DOMINION FOUNDRIES AND STEEL, LIMITED
P.O. BOX 460
HAMILTON, ONTARIO, CANADA
L8N 3J5

September 7, 1976

Betz Environmental Engineer,
1 Plymouth Meeting Mall,
PLYMOUTH MEETING, Pennsylvania,
19462
U.S.A.

Attention - Mr. Dave Lindsay

Dear Dave:

Please find attached production data sheets and cast times for #1 Blast Furnace, August 24 - 27, 1976 corresponding to your sampling schedule on the Baghouse By-Pass Stack, as well as strip charts for:

- Hot Blast Temperature
- Hot Blast Pressure
- B.F. Top Gas Temperature
- B.F. Top Pressure

and Cold Blast Flow Rate for the corresponding time period of testing.

Additional data:

Weight of personnel monitor cyclone catch

Sample 1	1.0921 mg
Sample 2	19.913 mg

Coke Strength from South Coke Plant
Aug. 25/76 Stability No. 57.9
Hardness No. 60.8

Amperage on Fan Motor based on Fan Louvre modulation:

100%	340-60 amps
70%	320
40%	280

Yours truly,

C-56 A. Kruzins
c/o Blast Furnace Office

AK:jp
ENCL.

DOMINION FOUNDRIES AND STEEL, LIMITED
P.O. BOX 460
HAMILTON, ONTARIO, CANADA
L8N 3J5

June 25, 1976

Mr. David Lindsey,
Betz Environmental Engineers,
1 Plymouth Meeting Mall,
PLYMOUTH MEETING, Pennsylvania,
19462,
U.S.A.

Dear Dave:

RE - #1 BLAST FURNACE BAG HOUSE

Please find attached a fan curve for our #1 blast furnace bag house fan. Inlet temperatures to the fan are presently in the 120°F - 150°F range and the fan amps are approximately 360. This converts to 1670 HP. Voltage on the motor is 2400. Design HP for the motor is 1500.

The system is operated with the louvres all the way open during a cast. In colder weather, amperage went up to 380 with the louvres all the way open.

Mr. R. Bean talked with Mr. Morrison and suggested a couple of minor modifications so that now the Morrison design meets Dofasco specifications.

If there are any more questions, do not hesitate to call.

Yours truly,

M. Greenfield
Air & Water Quality Engineer

MG:jp
ENCL.

T-9213

FM-C-903

.LDONS ENGINEERING LTD., CAMBRIDGE, ONTARIO

PERFORMANCE CURVE FOR:-

FAN TYPE #6550 MH. DWDI (WITH INLET CONES/ILD'S) ARR. 3 CLASS 4

FAN SPEED 880 RPM WHEEL DIA. 83⅛ TEMP. 120°F BAROMETER 29.62 HG

GAS DENSITY .0644 LBS/FT³ FAN SERIAL NO. 743099-1

CAST HOUSE FUME CONTROL FAN

REC'D DF & S ENG. DEPT. ______

COPY TO N. J. Greenfield (1) BY R. B.

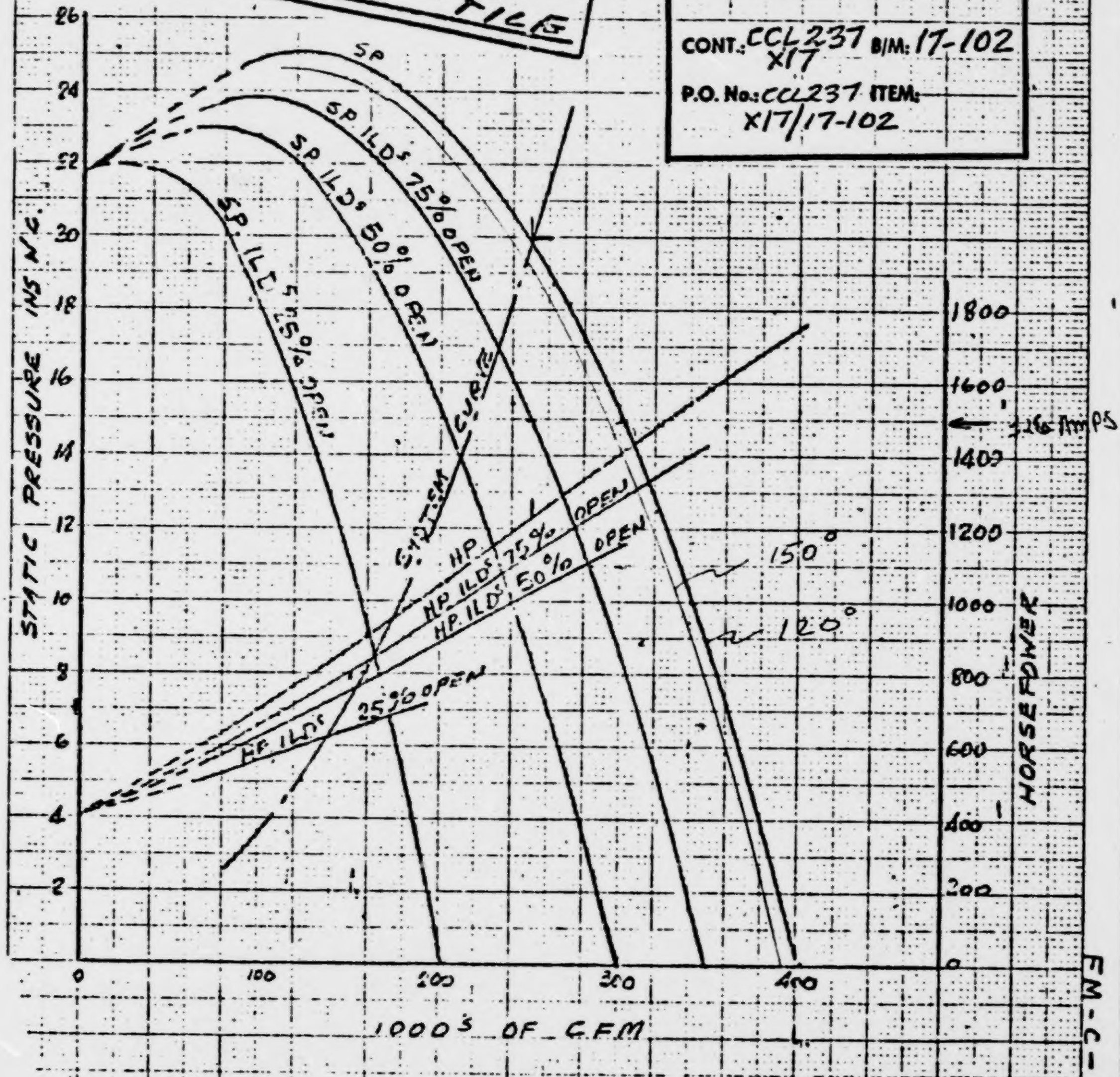
N. Luckington (1) ON Oct. 14/75

FILE

A. G. McKEE & CO. LTD.

CONT.: CCL237 X17 B/M: 17-102

P.O. No.: CCL237 ITEM: X17/17-102



46 1473

KEUFFEL & ESSER CO.

FM-C-903

5.

Report SS7704

SPARK SOURCE MASS SPECTROMETRIC ANALYSIS OF FIFTEEN SAMPLES OF BLAST FURNACE CAST HOUSE EMISSIONS

March 1977

by

Dr. E. Hunter Daughtrey, Jr.
J. Kent Bostick, Jr.

Northrop Services, Inc.
Research Triangle Park, North Carolina

FOREWORD

This work was performed under task instruction #4 of work order 2.1 (T.D. 2.1-2) of contract 68-02-2566 in support of the Environmental Monitoring and Support Laboratory, Environmental Research Center, Research Triangle Park, North Carolina.

Fifteen particulate samples of blast furnace cast house emissions plus two blank glass fiber filters were analyzed by spark source mass spectrometry to determine their elemental composition.

1. EXPERIMENTAL

1.1 Sample Preparation

Following the suggestion of the customer, attempts were made initially to physically remove the sample particulate matter from the glass fiber filters by scraping with a Teflon-coated spatula. This proved unsuccessful, since as much filter as sample was removed by this process.

Removal was achieved by boiling the filter in 10 ml of constant boiling aqua regia to extract the sample from the filter. The filter was removed from the acid, the acidic sample solution spiked with 1 ml each of 100 ppm erbium and 1000 ppm yttrium stock internal standard solutions, and as appropriate weighed amount of spectroscopic-grade graphite powder added. The sample/graphite slurry was evaporated to dryness under an infrared lamp. The dried mixture was shaken in a mixing mill to promote homogeneity, and then compacted into electrodes in the standard manner.

The blank glass fiber filters were treated in the same manner as the samples to determine their contribution to the background and to determine lower limits of detection of the elements found.

1.2 Analysis

The electrodes were analyzed using the electrical detection/computer data system of the mass spectrometer. Duplicate runs at each of five different multiplier gain settings were made in order to cover the full concentration range of the samples. The electrical detection data is corrected for differences in relative sensitivity between the elements. The data processing program has also been modified to avoid most of the commonly encountered interferences found with a graphite electrode matrix. An evaluation of the electrical detection/computer system has been performed, the report of which is in preparation.

2. RESULTS AND DISCUSSION

2.1 Sample Preparation

The chief difficulty with the analysis of these samples was due to the high background obtained for several elements in the glass fiber filters. The aqua regia dissolution necessary to remove the sample from the filter was more severe sample pretreatment than normally performed in SSMS analysis. Some carry-over of filter material was unavoidable in order to remove the sample material as completely as possible.

2.2 Analysis of the Blank Filters

Analysis of the aqua regia wash solution of duplicate blank glass fiber filters was performed. The results of the analyses (in micrograms of each element) were averaged, the standard deviation found (via the small number statistics approximation[1]), and the detection limits calculated from the standard deviation of the blank values.[2] This information is presented in Table 2-1.

2.3 Analysis of Samples

Since blank values were substantial for several elements, the computer data system was instructed to report results in micrograms rather than directly in sample concentration. The blank level (in ug) was subtracted from the weight of the sought-for element in the sample. This net weight of the element in the sample was compared to the detection limit, and reported as present if above the LD. The net weight of the element (in ug) was then divided by the net weight of the sample (in grams), as given in the tabulation accompanying the samples, to yield the concentration of the element in the sample. This assumes 100% recovery for all elements, so some results may be expected to be biased low. The results of the analysis are given in Table 2-2 through 2-4.

2.4 Potential Interferences

Examination of the mass spectra revealed less interference than expected from molecular ions of major elements in combination with chlorine (from the HCl of the aqua regia). This would indicate that a large portion of the chlorine must have volatilized on evaporation of the acid from the sample/graphite slurry. Elements which may be interfered with and the potential interferants are: Cu^+($Si\ Cl^+$); Co^+($Mg\ Cl^+$); Se^+ ($Ca\ Cl^+$, KCl^+); and, Nb^+ ($Fe\ Cl^+$).

Elements not reported for obvious cases of interference are: Ta (source parts), In (electrode holders), Er and Y (internal standards), S (N and O), Cl (acid), and F (Fe^{+3}, iron matrix). Nickel was not report in most cases due to interference from carbon and iron, only when its concentration was sufficient to see the very insensitive (but interference-free) $^{61}Ni+2$ isotope (30.5 m.u.) was nickel reported.

2.5 Estimates of Precision and Accuracy

Replicate scans were made at each multiplier gain setting to provide an estimate of the precision of analysis. The average % RSD ranged from 30-40% for each of the samples, which was reasonable compared to the 35% RSD normally associated with survey electrical detection scans. Not measured in the above uncertainty is that of sample preparation, which is likely larger than normal, given the usual sample pretreatment procedure.

With regard to accuracy, a negative bias may be expected due to incomplete extraction of the sample from the filter, but it should be small relative to the uncertainty of analysis. Any bias observed due to relative sensitivity differences between elements, should be removed by the element detail calibration of the data system.

Despite the larger than normal uncertainty and possible slight bias, the analyses should be well within the ± factor of 2 in the request for analysis.

3. CONCLUSION

Fifteen blast furnace cast house particulate samples were analyzed by spark source mass spectrometry. Due to high levels of several elements in the blank filters, full characterization of the samples was not possible. The elements which were quantitated should be well within the I factor of two specified in the analysis request.

References

1. R. B. Dean and W. J. Dixon, Anal. Chem 23, 636 (1951)

2. L. A. Currie, Anal. Chem 40, 587 (1968)

Table 2-1

Analysis of Blank Glass Fiber Filters

Results in Micrograms

Element	Blank	Std. Deviation	Detection Limit*
Ba	9.1	4.82	15.9
Sn	.445	.614	2.02
Zr	1.28	1.30	4.29
Sr	6.56	1.02	3.37
Se	4.58	2.48	8.18
Zn	26.8	2.49	8.23
Cu	8.6	1.85	6.10
Co	15.2	17.5	57.8
Fe	110	27.1	89.4
Mn	4.31	.196	.65
Cr	34.4	18.1	59.7
V	.798	.031	.10
T_1	41.6	42.6	140
Sc	2.89	1.47	4.85
Ca	4020	1067	3520
K	3419	1298	4280
P	2.65	1.02	3.37
Si	5080	3010	9930
Al	570	119	393
Mg	525	5	15
Na	4110	872	2880

*Detection Limit = 3.3 x Standard Deviation of Blank.

Table 2-2

Analysis of Blast Furnace Cast House Particulates

Results in μg/g unless otherwise noted

Sample # Weight	C778	C783	C864	C886	C903
	48.5 mg	13.5 mg	111.1 mg	8.6 mg	4.2 mg
Element					
Bi	*		.45		
Pb	305	1.3%	327	3046	2060
Tl		8	.8		
Ce	7.4	6.5	1.3	4.6	
La	0.5	2.2		3.5	
Ba	<330**	1380	348	2744	<3780
Cs		80	6.1		
I		270	20	130	
Te		41.5		95	
Sb		36			
Sn	<41	<148		<235	<480
Cd					
Ag	2.9	370		27	45
Rh					
Ru			7.5		
Mo		260	66		71
Nb			1.9	17	
Zr	<89	<320	<39	<500	<1024
Sr	162	<250	102	<395	<810
Rb	13	710	180		1120

*Blank indicates value was less than 1 μg/g

**Less than values due to high background in filter (LLD = 3.3 x σ of blank)

Table 2-2 Continued

Sample # Weight	C778	C783	C864	C886	C903
Element					
Br	48	180	19	300	590
Se	<170	<600	<74	<960	<1950
As	4.3	7.4	.63	1.2	4.8
Ga	40		7.2		
Zn	<170	2540	580	<960	<1980
Cu	<125	<450	160	<710	<1450
Ni					
Co	1220	<4300	1970	8700	<13.8%
Fe	13%	25.8%	37%	13%	20.1%
Mn	2.1%	17.1%	6.1%	12%	5.0%
Cr	<1240	<4440	<540	<7000	<1.43%
V	33	163	42	12	<24
Ti	<2890	<1%	<1260	<1.6%	<3.3%
Sc	<101	<360	<43	<560	<1150
Ca	<7.3	<26%	<3.2%	<41%	<84%
K	<8.8%	<32%	9.4%	<50%	<100%
P	<69	1700	1050	<400	3400
Si	<20%	<73%	13%	<100%	<100%
Al	<8100	<2.9%	<3510	<4.6%	<9.4%
Mg	<3100	<1000	5400	<1700	<1.43%
Na	<6%	<21%	<2.6%	<33%	<68%

Table 2-3

Analysis of Blast Furnace Cast House Particulates

Results in μg/g unless otherwise noted

Sample # Weight	C904	C905	C906	C907	C909
	224.3 mg	6.8 mg	10.1 mg	9.5 mg	56.2 mg
Element					
Bi	*	5.9	1	6.3	
Pb	76	1.1%	850	1050	283
Tl		5.9			22
Ce	5.5		11		18
La		1.5	10		1.6
Ba	71	<2340**	<1574	<1670	<283
Cs					17
I	1030	725	83	209	
Te		72	3		15
Sb	2.4	79	26	21	
Sn	18	<297	<200	<213	<36
Cd	3.6				
Ag	81	622	121	123	29
Rh	6.5				
Ru	10.7	40		50	
Mo	60	462	80	235	34
Nb	30				52
Zr	<19	<630	<426	<450	<76
Sr	223	1040	<1390	<1260	212
Rb	3.1	228	574		206

*Blank indicates value was less than 1 μg/g

**Less than values due to high background in filter (LLD = 3.3 xσ of blank)

Table 2-3 Continued

Sample # Weight	C904	C905	C906	C907	C909
Element					
Br	472	144	37	926	311
Se	44	<1200	<812	<860	219
As	2.0		3.0	4.7	1.8
Ga	5.2	128	5.9		176
Zn	1.1%	<1220	<820	<874	400
Cu	1060	1620	<600	642	658
Ni	2450				
Co	8800	1.1%	5440	<6080	2120
Fe	Major	Major	10.4%	30%	38%
Mn	6890	20.6%	6.1%	10.5%	3.5%
Cr	7.3%	<8800	<5940	7160	2.3%
V	71	<15	<9.9	13	68
Ti	6820	<2.0%	<1.4%	<1.5%	2490
Sc	37	<713	<480	510	<85
Ca	<1.6%	<52%	<35%	<37%	<6.3%
K	5%	<63%	<42%	<45%	<7.6%
P	<15	3400	4540	574	735
Si	<4.4%	<100%	<98%	<100%	<18%
Al	<1750	12.5%	<3.9%	3.6%	<6990
Mg	<67	6.9%	<1485	<1600	3810
Na	<1.3%	<42%	<28%	<30%	<5.1%

Table 2-4

Analysis of Furnace Cast House Particulates

Results in µg/g unless otherwise noted

Sample # Weight	C918	C939	C940	C941	C942
	18.5 mg	13.5 mg	122.5 mg	35.6 mg	58.4 mg
Element					
Bi	3		7.4	1.4	9.6
Pb	1290	1185	860	921	3730
Tl	*				
Ce	4.3	1.8	1.9		
La				.4	
Ba	<860	<1180**	<130	<447	<270
Cs				17	
I	60	144	76		45
Te	2.7	14	50	7.3	28
Sb	17.5	4.8	2.8	16.4	63
Sn	<110	<150	62	<56	<34
Cd	1.6			5	
Ag	34	40	17	11	39
Rh					
Ru	43	39			
Mo	18	127	31	180	54
Nb		8.9	95		23
Zr	<230	<320	<35	<120	<74
Sr	886	490	210	97	675
Rb	590	440	67	177	265

*Blank indicates value was less than 1 µg/g

**Less than values due to high background in filter (LLD = 3.3 x σ of blank)

Table 2-4 Continued

Sample # Weight	C918	C939	C940	C941	C492
Element					
Br	340	690	69		96
Se	<440	<610	71	<230	<140
As	1.0	12		3.4	9.4
Ga		4.4	27	2.2	22
Zn	540	<610	158	<230	970
Cu	1500	<450	206	<170	850
Ni					
Co	6860	<4280	162	<1630	4440
Fe	Major	Major	23%	62%	Major
Mn	15.4%	21%	2.6%	6.2%	8.7%
Cr	<3240	<4440	<490	<1680	5140
V	86	58	46	<3	62
Ti	7950	<1.0%	<1140	<3930	2900
Sc	<260	355	<39	<135	<83
Ca	Major	<26%	<2.9%	<9.9%	<6%
K	Major	<32%	3.5%	<12%	18%
P	5620	6830	346	<96	2670
Si	<50%	<74%	<8.1%	<28%	<17%
Al	9.7%	<2.9%	<3210	<1.1%	<6700
Mg	3.0%	2.2%	<122	6.2%	1800
Na	Major	<21%	<2.3%	<8.1%	<48000

Report SS7705

SPARK SOURCE MASS SPECTROMETRIC ANALYSIS OF BLAST FURNACE CAST HOUSE BAGHOUSE SAMPLE

by

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J. Kent Bostick, Jr.

April 1, 1977

Northrop Services, Inc.
Research Triangle Park, N.C.

FOREWORD

A sample of blast furnace cast house dust was analyzed by spark source mass spectrometry to determine its elemental composition.

This work was performed under task instruction #5 of Work Order 2.1 (T.D. 2.1-2) of contract 68-02-2566 in support of the Environmental Monitoring and Support Laboratory, Environmental Research Center, Research Triangle Park, North Carolina.

Task instruction received March 14, 1977

Analysis completed April 1, 1977

Section I

EXPERIMENTAL

1.1 Sample Preparation

The sample was low temperature dry-ashed to remove the organic content. Physically, the sample was black with metallic flecks which ashed to brown-black powder with metallic flecks, 93.6% ash.

The resultant ash was mixed 50:50 by weight with graphite, the mixture spiked with erbium and yttrium internal standards, the sample/graphite slurry evaporated to dryness under an infrared lamp. The dry mixture was then shaken in a mixing mill to promote homogeneity, and electrodes were prepared in the standard manner.

1.2 Analysis

The electrodes were prepared using the electrical detection/computer data system of the mass spectrometer. The full concentration range of the sample was covered by making runs at various multiplier gain settings. The analyses were performed in the usual manner.

Section II

RESULTS AND DISCUSSION

2.1 Sample Preparation

No difficulties were encountered in the sample preparation procedures. Sufficient sample was available to yield reasonable elemental sensitivity for all samples.

2.2 Analysis of Samples

The results of the analyses are given in Table 2. Elements not reported were not seen at the maximum gain setting of the mass spectrometers. "Less than" (<) indicates the probability of interference on the isotope used for quantification of an element. Of the elements requested, beryllium and sulfur were not done, as calibration for these elements in the presence of interference of most environmental samples is not practical by electrical detection. Photoplate capabilities are restricted at present due to a very limited supply of plates and the absence of the densitometer which is being computer control retrofitted. Low biased response for the halogens is expected since the samples were low temperature ashed.

Normal precision and accuracy should be observed for these samples well within the criteria set in the analysis request (within order of magnitude).

Lower limits of detection are difficult to estimate for elements not seen using the computer data system (due to limitations of the output options of the computer). As a rough approximation (but should be within the order of magnitude accuracy), the detection limit for elements not reported is .1 ppm times the % ash of the sample.

Section III

CONCLUSION

A sample of blast furnace cast house dust was analyzed by spark source mass spectrometry (electrical detection). Full elemental characterization was performed from trace to major components of the ashed sample.

Table 2

ANALYSIS OF BLAST FURNACE BAGHOUSE SAMPLE

(results in μg/g)

Element	Concentration
Pb	2100
Ce	.42
La	.17
Ba	36
Te	1.3
Sb	8.2
Sn	1.6
Cd	25
Ag	1.1
Mo	580
Nb	25
Zr	36
Sr	110
Rb	245
Br	<360
Se	<240
Ga	230
Zn	3800
Cu	940
Co	1360
Fe	470,000
Mn	49,000

Table 2 Continued

Element	Concentration
Cr	1100
V	200
Ti	1500
Sc	460
Ca	87,000
K	140,000
Cl	2700
P	2400
Si	52,000
Al	760
Mg	8700
Na	39,000

Approximate L_D for elements not reported - .09 µg/g.

D. BETHLEHEM STEEL CORPORATION

CAST HOUSE EMISSION EVALUATION DATA

PARTICULATE EMISSIONS TEST RESULTS (1)

"E" Blast Furnace(2) - Baghouse Inlet

BETHLEHEM STEEL CORPORATION

JOHNSTOWN PLANT

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Test No.	Date	Gas Temp. (°F)	Evacuation Rate ACFM x 10^3	Evacuation Rate DSCFM x 10^3	Concentration (gr/dscf) Front	Concentration (gr/dscf) Back	Concentration (gr/dscf) Total	Capture Rate (lb/hr) Front	Capture Rate (lb/hr) Back	Capture Rate (lb/hr) Total	Emission Factor (lb/ton) Front	Emission Factor (lb/ton) Back	Emission Factor (lb/ton) Total	Cast Duration (min.)	Productio (tons/cast
1	10/6/76	100	211.9	191.9	.0399	.0011	.0410	65.6	1.7	67.3	0.18	0.004	0.18	31	191
2	10/6/76	115	177.6	160.1	.0511	.0019	.0530	70.1	2.7	72.8	0.12	0.005	0.13	28	252
3	10/7/76	86	179.9	171.2	.0402	.0007	.0409	58.8	1.0	59.8	0.39	0.007	0.40	39	99
4	10/7/76	98	172.5	160.8	.0574	.0006	.0580	79.0	0.8	79.8	0.60	0.006	0.60	39	84
5	10/11/76	91	249.0	225.2	.0342	.0018	.0360	65.9	3.6	69.5	0.18	0.010	0.19	34	200
6	10/12/76	85	259.1	243.1	.0262	.0018	.0280	54.6	3.8	58.4	0.13	0.009	0.14	32	222
7	10/12/76	97	245.5	227.2	.0403	.0021	.0424	78.4	4.0	82.4	0.20	0.009	0.21	22	138
8	10/13/76	90	251.1	236.7	.0220	.0014	.0234	48.4	3.0	51.4	0.26	0.018	0.28	33	100
9	10/13/76	103	246.4	220.0	.0234	.0022	.0256	44.2	4.1	48.3	0.14	0.013	0.16	39	201
10	10/18/76	51	284.8	294.9	.0227	.0009	.0236	57.3	2.4	59.7	0.23	0.009	0.24	50	205
11	10/18/76	71	307.7	297.6	.0305	.0008	.0313	78.9	2.0	80.9	0.28	0.007	0.28	32	151
12	10/19/76	64	308.9	296.2	.0277	.0018	.0295	70.4	4.5	74.9	0.14	0.009	0.15	25	207
13	10/19/76	80	300.5	286.9	.0256	.0014	.0270	63.0	3.5	66.5	0.13	0.007	0.14	35	260
14	10/14/76	81	322.1	297.6	.0355	.0027	.0382	90.4	7.0	97.4	0.28	0.022	0.30	20	107
15	10/14/76	93	330.5	300.2	.0239	.0039	.0278	61.4	10.1	71.5	0.11	0.018	0.12	21	203
16	11/8/76	55	467.7	466.7	.0107	.0022	.0129	43.8	9.0	52.8	0.19	0.035	0.23	32	122
17	11/9/76	78	450.5	433.1	.0200	.0020	.0220	74.0	7.2	81.2	0.15	0.018	0.17	29	234
18	11/10/76	61	438.2	440.9	.0060	.0010	.0070	22.7	3.8	26.5	0.06	0.009	0.08	38	214
19	11/10/76	67	428.6	422.0	.0082	.0026	.0108	29.5	9.4	38.9	0.11	0.026	0.14	46	218
										Averages	0.20	0.02	0.22		

(1) Testing conducted by Bethlehem Steel Corporation

(2) Normally a ferromanganese furnace. During this testing program furnace was producing basic iron.

TABLE NO. 1

Particulate Emissions Test Results (1)
BETHLEHEM STEEL CORPORATION
BETHLEHEM PLANT

"E" Blast Furnace Through Hood Exhaust Duct Side Port

TEST	TEMP	FLOW		CONCENTRATION (gr/dscf)			EMISSION RATE (lb/hr)			EMISSION FACTOR (lb/Ton)		
	°F	ACFM	DSCFM	FRONT	BACK	TOTAL	FRONT	BACK	TOTAL	FRONT	BACK	TOTAL
BF-1	106	89400	81884	.0373	.0502	.0875	26.17	35.23	61.41	.069	.093	.163
BF-2	108	92400	84430	.0905	.0367	.1272	65.49	26.56	92.05	.190	.077	.267
BF-3	108	90100	81479	.0346	.0221	.0567	24.16	15.43	39.60	.048	.031	.079
BF-5	118	304100	272454	.0581	.0587	.1165	135.68	137.08	272.06	.253	.256	.509
BF-6	116	289900	260795	.0374	.0352	.0727	83.60	78.68	162.51	.305	.288	.594
BF-7	97	294800	272370	.0307	.0144	.0451	71.67	33.61	105.29	.202	.095	.296
BF-9	139	163800	145264	.1069	.0125	.1194	133.10	15.56	148.66	.262	.031	.292
BF-10	128	159400	143780	.0823	.0155	.0978	101.43	19.10	120.53	.229	.043	.272
B-11	114	165100	151231	.0918	.0246	.1163	118.98	31.89	150.75	.228	.061	.289

(1) Tests conducted in the horizontal axis of exhaust duct

TABLE NO. II

Particulate Emissions Test Results(1)

BETHLEHEM STEEL CORPORATION
BETHLEHEM PLANT

"E" Blast Furnace Through Hood Exhaust Duct Top Port

TEST	TEMP	FLOW		CONCENTRATION (gr/dscf)			EMISSION RATE (lb/hr)			EMISSION FACTOR (lb/Ton)		
	°F	ACFM	DSCFM	FRONT	BACK	TOTAL	FRONT	BACK	TOTAL	FRONT	BACK	TOTAL
EBF-1	106	85264	79265	0.037	0.026	0.063	25.14	17.66	42.80	0.07	0.05	0.12
EBF-2	127	93045	82395	0.047	0.032	0.079	33.19	22.60	55.79	0.10	0.07	0.17
EBF-3	110	89489	81747	0.056	0.003	0.059	38.54	2.10	40.64	0.08	0.004	0.084
EBF-5	113	312704	283410	0.046	0.021	0.067	111.74	51.01	162.75	0.21	0.10	0.31
EBF-6	111	312681	285247	0.042	0.010	0.052	102.69	24.45	127.14	0.38	0.09	0.47
EBF-7	91	310926	294222	0.034	0.014	0.048	85.74	37.83	123.57	0.24	0.11	0.35
EBF-9	128	154597	138193	0.086	0.007	0.093	101.87	8.29	110.16	0.21	0.02	0.23
EBF-10	128	158776	142360	0.099	0.010	0.109	120.80	12.20	133.00	0.27	0.03	0.30
EBF-11	110	154343	142375	0.118	0.013	0.131	144.00	15.86	159.86	0.27	0.03	0.30

(1) Tests conducted in the vertical axis of exhaust duct.

TABLE III

Particulate Emission Test Results
BETHLEHEM STEEL CORPORATION
BETHLEHEM PLANT

"E" Blast Furnace Through Hood Exhaust Duct Average of Two Ports

TEST	TIME MIN.	TEMP °F	FLOW ACFM	FLOW DSCFM	CONCENTRATION (gr/dscf) FRONT	BACK	TOTAL	EMISSION RATE (lb/hr) FRONT	BACK	TOTAL	EMISSION FACTOR (lb/Ton) FRONT	BACK	TOTAL
EBF-1	40	106	87332	80575	0.037	0.038	0.075	25.56	26.45	52.11	0.07	0.07	0.14
EBF-2	30	118	92723	83413	0.069	0.034	0.103	49.34	24.58	73.92	0.15	0.07	0.22
EBF-3	40	109	89795	81613	0.045	0.013	0.058	31.35	8.77	40.12	0.07	0.02	0.09
Avg.		111	89950	81867	0.050	0.028	0.078	35.45	19.93	55.38	0.10	0.05	0.15
EBF-5	40	116	308402	277932	0.052	0.040	0.092	123.71	94.05	217.76	0.23	0.18	0.41
EBF-6	35	114	301291	273021	0.040	0.023	0.063	93.15	51.57	144.72	0.34	0.19	0.53
EBF-7	65	94	302863	283296	0.032	0.014	0.046	78.71	35.72	114.43	0.22	0.10	0.32
Avg.		108	304185	278083	0.041	0.026	0.067	98.52	60.45	158.97	0.26	0.16	0.42
EBF-9	31	134	159199	141729	0.096	0.010	0.106	117.49	11.93	129.42	0.24	0.03	0.27
EBF-10	35	128	159088	143070	0.091	0.013	0.104	111.12	15.65	126.77	0.25	0.04	0.29
EBF-11	35	112	159722	146803	0.105	0.019	0.124	131.49	23.88	155.37	0.25	0.05	0.30
Avg.		125	159336	143867	0.097	0.014	0.111	120.03	17.15	137.18	0.25	0.04	0.29